DOCUMENT RESUME

ED 404 148 SE 055 246

AUTHOR	Rogers, Diana, Ed.
TITLE	Cycles for Science: Curriculum Supplement for Chemistry (Grades 9-12).
INSTITUTION	Steel Recycling Inst., Pittsburgh, PA.
PUB DATE	94
NOTE	64p.
AVAILABLE FROM	Steel Recycling Institute, 680 Andersen Drive, Pittsburgh, PA 15220-2700 ($12.75).
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052) -- Guides - Classroom Use - Instructional Materials (For Learner) (051)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Chemistry; Instructional Materials; *Metal Industry; *Recycling; Science Education; Secondary Education; *Supplementary Reading Materials; Textbooks

ABSTRACT

This document was developed in cooperation with secondary teachers and solid waste management professionals. The goal is to integrate steel recycling, natural resource conservation, and solid waste management into science learning. Basic concepts from the following chemistry units have been used to design the lessons and activities: transition metals, chemical reactions, and changes of state and electron configuration. Three lessons are entitled: (1) Supply & Demand; (2) Collect & Haul; and (3) Sort & Produce. Each lesson begins with a background for the teacher which includes: key terms, motivation, demonstration, and evaluation. The background section for the student provides in-depth information on the lesson. The "teacher activity" section contains planning, preparation and safety tips and the "student activity" section provides step-by-step procedures for completing the activity and analyzing the data. Appendixes include a glossary, a list of resources, and a teacher evaluation form. Contains 18 references. (AA)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 404 148

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN **OTHER THAN PAPER COPY** HAS BEEN GRANTED BY

M Norton

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Cycles for Science

Curriculum Supplement for Chemistry (Grades 9–12)

A Steel Cycles Program from the Steel Recycling Institute

BEST COPY AVAILABLE

The Steel Recycling Institute gratefully acknowledges the contribution of the educators and technicians who assisted in the development and field testing of these materials.

Editor/Writer

Diana Rogers
Eco Partners, Inc.

Associate Editors/Writers

Carol Laymon
Eco Partners, Inc.

Carol Damian
Dublin High School

Educational Reviewers

Betty Altfater
Sarah Binder
Jonathan Chorpenning
Vonnie Christiansen
Lois E. DeLaney-Cooper
John B. Grena
Monroe E. Harbage
Robert Hateley
Barbara Hilligoss
Kathleen Jones
Philip Lampe
Chris McCabe
Deborah L. Mills
Susan E. Rouch
Karen A. Russell
Jodi Schwartz
Franklin Tuttle
Gardner M. Watkins
Sue Wheeler
Mark D. Wylie

Technical Reviewers

Jack Crossett
LTV Steel Company

Kent Kiser
Scrap Processing and Recycling (publication of the Institute of Scrap Recycling Industries)

Contributors: Curriculum Development Workshop

Diane Cantrell, Ph.D.
Ohio Department of Natural Resources

Lois E. Delaney-Cooper
Marion-Franklin High School

Kay Harmless
Tipton School District

Jan Lingenfelter
Washington State Department of Ecology

Steve Lippitt
Groveport-Madison High School

Robin Riordan, Ph.D.
The Ohio State University

For Additional Copies:

Cycles for Science curriculum supplements for Biology, Chemistry, General Science and Earth Science, Physics, and Community Volunteer Projects are available from the:

STEEL RECYCLING INSTITUTE
680 Andersen Drive
Pittsburgh, PA 15220-2700
412/922-2772

© 1994 Steel Recycling Institute. All rights reserved. Permission granted to educators to reproduce for classroom use.
Printed on **recycled** paper. Printed with soy ink.

BEST COPY AVAILABLE

Foreword

Steel Recycling Institute

The Steel Recycling Institute (SRI) is dedicated to promoting and sustaining steel recycling across the country. The SRI recognizes the value of incorporating recycling and solid waste management information into the educational process and encourages responsible solid waste handling. ***Cycles for Science*** provides teachers and students with a greater understanding of steel and steel can recycling and encourages responsible solid waste handling practices.

Steel is America's most recycled material. Steel cans and other steel products are recycled into a variety of new steel products. A steel can may become part of a car, a bridge or perhaps a child's toy. Since steel can be recycled infinitely, the cycle continues as steel products are again recycled. Steel cans are collected for recycling through a variety of programs, including curbside, drop-off, multi-material buyback, and commercial/institutional recycling. In some communities, steel cans and other household steel products are collected for recycling automatically through magnetic separation at resource recovery facilities.

Recycling helps the environment, conserves natural resources and saves energy. The Steel Recycling Institute is proud to help provide opportunities for solid waste management education. While this program focuses on steel and steel can recycling, the SRI supports the recycling of all recyclable materials and promotes integrated solid waste management practices. Students who learn about recycling today will be well prepared for the resource management of tomorrow.

Bill

William M. Heenan, Jr.
President

Acknowledgements i
Foreword ii
Contents iii
About *Cycles for Science* iii
The Steel Cycle ..... iv-v
Planning Guide ..... vi-viii
Integrating Other Skills and Subject Areas ix

Lesson: Supply & Demand

Background: Teacher 1
Student 5

ACTIVITIES:

1. Making an Alloy
   Teacher 7
   Student 9
2. Nails in Solution
   Teacher 11
   Student 13

Lesson: Collect & Haul

Background: Teacher 15
Student 19

ACTIVITIES:

3. Recyclable Cars
   Teacher 21
   Student 25
4. Scratch or Dent
   Teacher 27
   Student 29

Lesson: Sort & Produce

Background: Teacher 31
Student 35

ACTIVITIES:

5. Sorting Commingled Metals
   Teacher 37
   Student 41
6. Melting Alloys
   Teacher 43
   Student 45

Appendix

Glossary 47
Bibliography 48
List of Figures/Tables 49
Did You Know? Steel Recycling 50
Resources 51
Teacher Evaluation 52

About Cycles for Science

Welcome to the ***Cycles for Science*** program designed by the Steel Recycling Institute to assist secondary teachers and students (grades 9–12) in meeting state and local goals for learning in Biology, Chemistry, General Science and Earth Science, and Physics. Curriculum supplements in each of these core areas of science contain project-oriented lessons and hands-on activities. Also available is a curriculum supplement for Community Volunteer Projects, appropriate for student groups and community organizations.

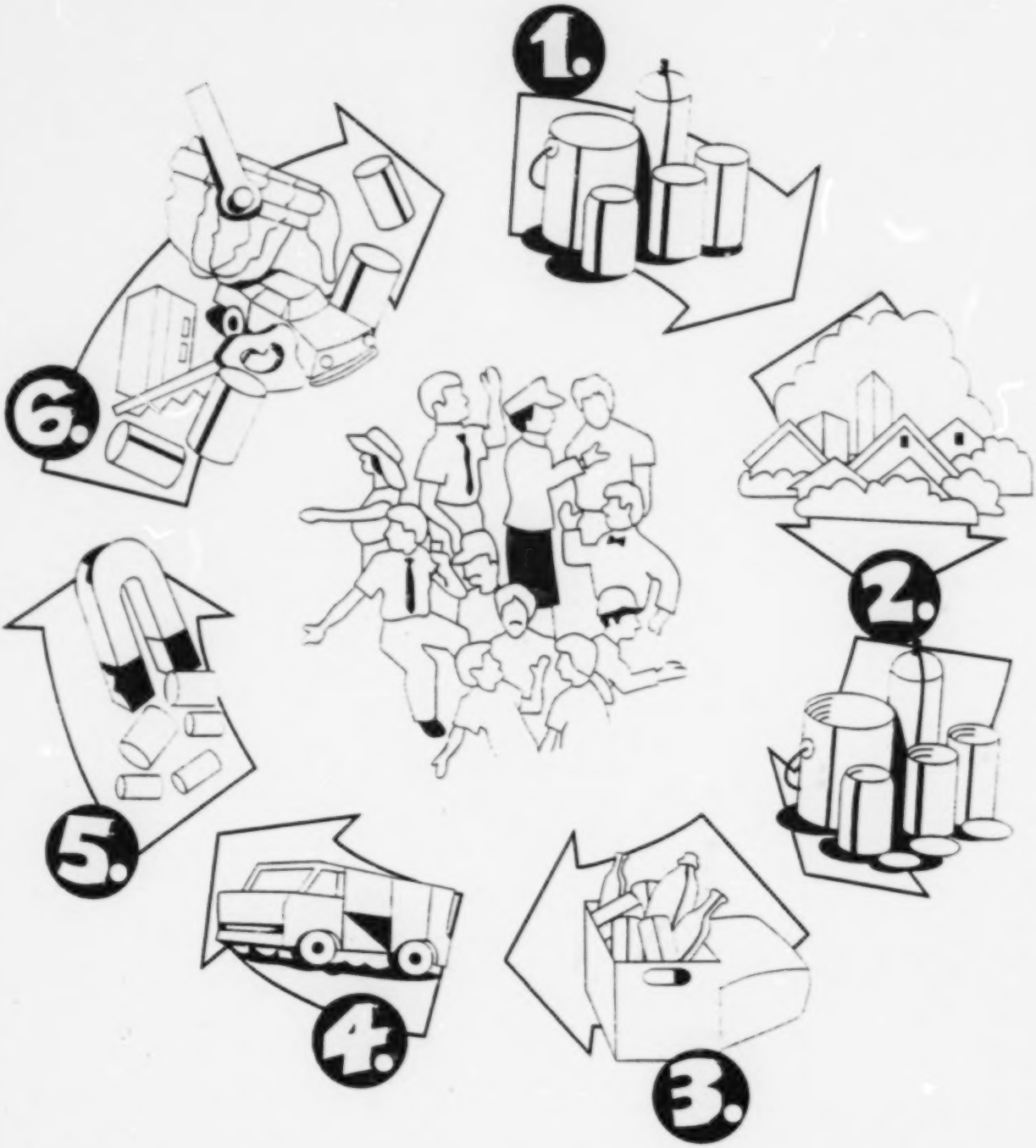
The motivation for creating ***Cycles for Science*** was requests from secondary teachers for activities which bring real-life science into the classroom. The goal of this program is to integrate steel recycling, natural resource conservation, and solid waste management into science learning.

Cycles for Science was developed in cooperation with secondary teachers and solid waste management professionals and is part of the Steel Cycles program for kindergarten through grade 12.

The Steel Recycling Institute

The Steel Recycling Institute (SRI) assists community leaders, recyclers, business people and educators in developing steel recycling programs and raising public awareness. Located in Pittsburgh, Pennsylvania, the SRI has established a network of regional offices to help communities create viable, sustaining steel recycling activity within existing programs. To supplement recycling activity and encourage long-term commitment to responsible solid waste management practices, the SRI is working toward the development of comprehensive educational programs.

The Steel Cycle



THE STEEL CYCLE		LESSON	ACTIVITY
	SUPPLY	Supply & Demand	1. Making an Alloy
	DEMAND	Supply & Demand	2. Nails in Solution
	COLLECT	Collect & Haul	3. Recyclable Cars
	HAUL	Collect & Haul	4. Scratch or Dent
	SORT	Sort & Produce	5. Sorting Commingled Metals
	PRODUCE	Sort & Produce	6. Melting Alloys

Planning Guide

Lessons at a Glance

This curriculum is designed to assist secondary teachers in meeting state and local goals for learning in Chemistry. Students will have the opportunity to engage in the use of critical thinking skills when participating in individual and group activities.

The lessons can be easily implemented by using materials and equipment commonly found in a science lab or available at a local retail store. The curriculum is "user-friendly" and provides background and step-by-step instructions that are ready to copy. Teachers are encouraged to go beyond the lessons and activities by encouraging the students to get involved in school and community waste reduction and recycling programs.

Basic concepts from the following Chemistry units have been used to design the lessons and activities:

- Transition metals
- Chemical reactions
- Changes of state
- Electron configuration

Lesson: Supply & Demand

In this lesson, students will become better acquainted with the trends and properties of transition metals used as alloys and to coat steel by examining alloy-like mixtures and performing chemical tests on common steel objects.

LEARNING OUTCOMES:

Activity 1. Making an Alloy

Students will be able to:

- predict the physical properties of alloy-like substances
- demonstrate that adding components to an alloy-like substance changes its physical properties
- describe and cite examples of how a change in one physical property affects other physical properties

Activity 2. Nails in Solution

Students will be able to:

- classify steel and galvanized steel according to reactions to acid, base, and salt solutions
- construct formulas to represent the reactions
- explain the chemical process of corrosion and how it can be used to make galvanized steel

Lesson: Collect & Haul

In this lesson, students will discover the role of transition metals in the manufacture of cars and select steel objects. This will be achieved through an understanding of automakers' efforts to design automobiles for reuse and recycling, and by performing physical tests on steel objects used for packaging and transporting materials.

LEARNING OUTCOMES:

Activity 3. Recyclable Cars

Students will be able to:

- describe the collection process for recovering automotive parts for reuse and recycling
- identify car parts by their composition and properties
- evaluate from a citizen's point of view the role of the consumer, carmaker and government in seeking solutions to car recycling

Activity 4. Scratch or Dent

Students will be able to:

- form a model of the metallic bonding and alloying of two or more metals
- predict the arrangement of atoms and electrons in the metallic structure
- describe the physical properties and function of steel objects used for packaging and transporting materials

Lesson: Sort & Produce

In this lesson, students will understand how the properties of transition metals can be used to sort or extract the metals from a mixture and how the addition of alloying elements affects the melting point of metals.

LEARNING OUTCOMES:

Activity 5. Sorting Commingled Metals

Students will be able to:

- describe the properties of aluminum, iron and lead
- identify metals in a mixture
- calculate the representative composition of metals extracted from a mixture

Activity 6. Melting Alloys

Students will be able to:

- observe the change in a metal from the solid to the liquid state
- identify differences in melting points of various alloys
- explain how the addition of alloying elements to a base metal may affect the melting point

How Each Lesson is Organized

- Background: Teacher
- Background: Student
- Activity: Teacher
- Activity: Student

1. Background: Teacher

Each lesson begins with a background for the teacher which includes:

- Key Terms
- Motivation
- Demonstration
- Content Development
- Learning Outcomes
- Extensions
- Independent Study
- Evaluation "Test Your Knowledge"

2. Background: Student

The *Background: Student* provides in-depth information on the lesson, not usually found in a high school text book. The key terms are highlighted in the student background. The student background is an excellent reference for you and your students in learning more about steel and steel can recycling.

3. Activity: Teacher

The *Activity: Teacher* contains planning, preparation and safety tips not included in the activity instructions for the students. Outlined in this section are the learning outcomes, time and materials needed, figures and tables used, collecting and analyzing data suggestions and the answer key for the "Drawing Conclusions" questions asked in the *Activity: Student*.

4. Activity: Student

The *Activity: Student* provides individuals or lab groups of students with step-by-step procedures for completing the activity, graphs/charts for collecting and analyzing data, and "Drawing Conclusions" questions that require student understanding of the activity.

Suggested Uses

In addition to classroom instructional use, the lessons and activities would be ideal for student science projects and individual research.

Integrating Other Skills and Subject Areas

You will find that the lessons and activities in this curriculum meet classroom goals for developing student skills and critical thinking while providing materials which can be integrated across subject areas.

LESSON:	SUPPLY & DEMAND		COLLECT & HAUL		SORT & PRODUCE	
ACTIVITY:	1 Making an Alloy	2 Nails in Solution	3 Recyclable Cars	4 Scratch or Dent	5 Sorting Commingled Metals	6 Melting Alloys
PROCESS SKILLS						
calculate				•	•	
classify	•	•	•	•	•	
form hypothesis	•					
form models/formulas		•		•		
identify control/variables	•	•				
interpret data/measure	•	•	•	•	•	•
observe/describe	•	•	•	•	•	•
perform experiment	•	•		•	•	•
predict	•		•		•	•
state a conclusion	•	•	•	•	•	•
CRITICAL THINKING SKILLS						
problem solving		•	•			
creative thinking	•	•	•	•	•	•
decision making	•		•		•	•
communication	•	•	•	•	•	•
collaboration	•	•	•	•	•	•
leadership			•	•	•	•
organization		•	•	•	•	•
OTHER SUBJECTS						
earth science		•	•	•	•	•
math					•	
physics	•	•	•	•	•	•
social studies			•	•	•	

LESSON

Supply & Demand

In this lesson, students will become better acquainted with the trends and properties of transition metals used as alloys and coatings of steel by examining alloy-like mixtures and performing chemical tests on common steel objects.

Key Terms

Key terms are highlighted in the *Background: Student* with definitions provided in the *Glossary*.

alloy	**base metal**	**galvanize**
alloying element	**ductility**	**malleability**

Motivation

Draw an analogy between baked goods and alloys of steel. On separate trays, set an assortment of baked goods, the ingredients of the baked goods, a variety of steel objects, and pure iron and other elements such as carbon and nickel which might have been used to make the steel objects.

Instruct students to examine the trays. Ask the following questions:

- What do all the baked goods have in common? *(All have flour as the basic ingredient.)*
- What gives each baked good its individual appearance and taste? *(Addition of other ingredients and the proportions)*
- How does this compare to steel? *(All steel items have iron as the basic ingredient. The different properties of steel items depend upon other elements added to the iron and their proportions.)*

Demonstration

Place a penny on a five-centimeter square piece of aluminum foil in a beaker of water. Allow it to stand overnight. Examine the aluminum foil the next day. It should be corroded at points of contact with the penny, and the water will be cloudy. Explain that corrosion is a change in a material resulting from chemical reaction with its environment. In this case, corrosion occurred where two different metals were joined together. The concept of corrosion is put to use in galvanized steel. Refer to *Background: Student*, page 6.

Content Development

Copy onto overhead transparencies *Crystal Structure of Iron*, page 3, and *Crystal Structure of Steel*, page 4. Copy and distribute to each student the *Background: Student*, pages 5 and 6. Display the transparencies and use the background reading as a reference in explaining metallic bonding and the properties of transition metals. Describe alloys of steel and the chemical process of corrosion. Use a chemistry text to review crystal packing structures and acid/base reactions.

Learning Outcomes

Activity 1. Making an Alloy

Students will be able to:

- predict the physical properties of alloy-like substances
- demonstrate that adding components to an alloy-like substance changes its physical properties
- describe and cite examples of how a change in one physical property affects other physical properties

Activity 2. Nails in Solution

Students will be able to:

- classify steel and galvanized steel according to reactions to acid, base, and salt solutions
- construct formulas to represent the reactions
- explain the chemical process of corrosion and how it can be used to make galvanized steel

Extension

The following activity expands on concepts introduced in this lesson.

METAL MANIA

Instruct students to monitor their households' purchases of metal items for one week. Ask them to cite every metal item from beverage cans to hangers. Compile a class list of the week's purchases. Classify the products according to use (e.g., personal products, food, home repair, office supplies) and rank the metals according to type (e.g., steel, aluminum, copper). Discuss the demand for metals in households and identify those metals which can and cannot be recycled. Develop a list of recommendations for reducing, reusing, and recycling metals in the home.

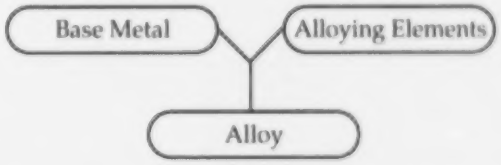
Independent Study

- Invent a steel toy for use outdoors in a sand box. Draw a sketch of it. Describe the conditions and chemical reactions to which the toy would be exposed. What properties should the steel have in order to withstand these conditions and chemical reactions?
- Visit a mill or other product manufacturing plant. Interview staff members in research, production, and quality control to identify the chemical processes they perform on the steel to ensure their products meet the demands of their customers.

Evaluation "Test Your Knowledge"

Evaluate student learning of the concepts introduced in this lesson. "Test Your Knowledge" suggestions:

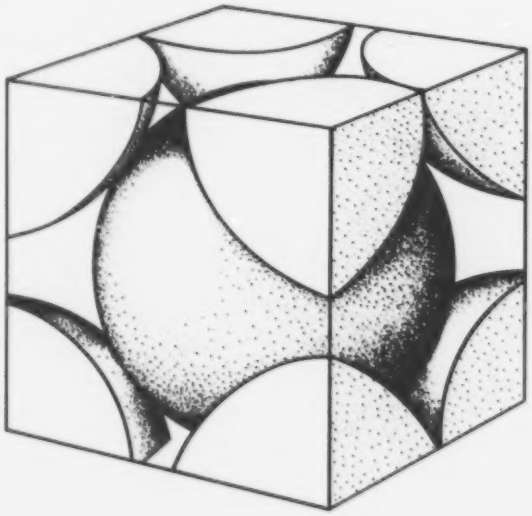
- Create a concept map for alloy, base metal, and alloying elements.



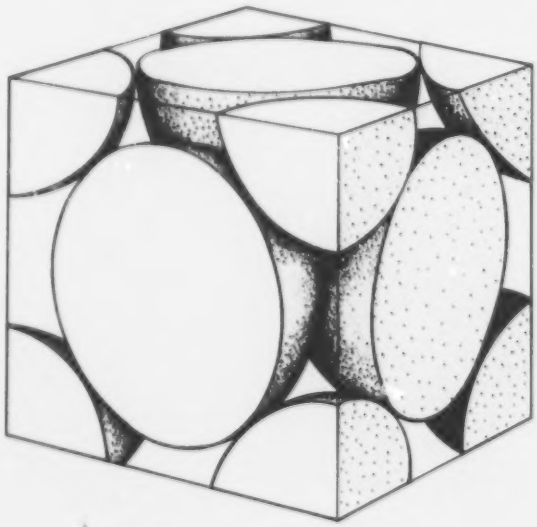
- Compile a list of steel and coated steel items used every day in school or at home. Describe the conditions to which these items are exposed and describe the properties of steel needed for each item to function properly.
- Use the key terms to write a story "A Day in the Life of a Metal Atom."

Crystal Structure of Iron

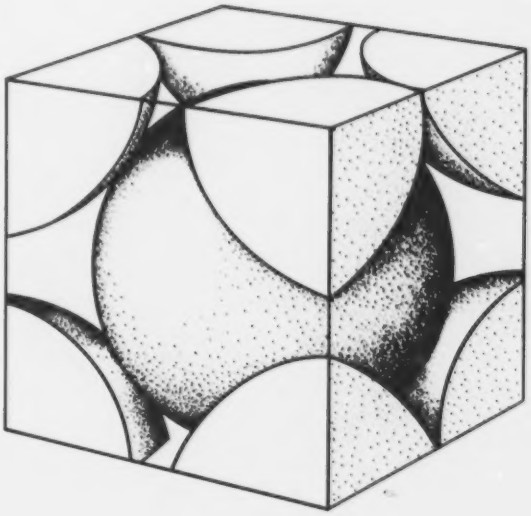
At normal temperatures, iron forms a body-centered cubic cell:



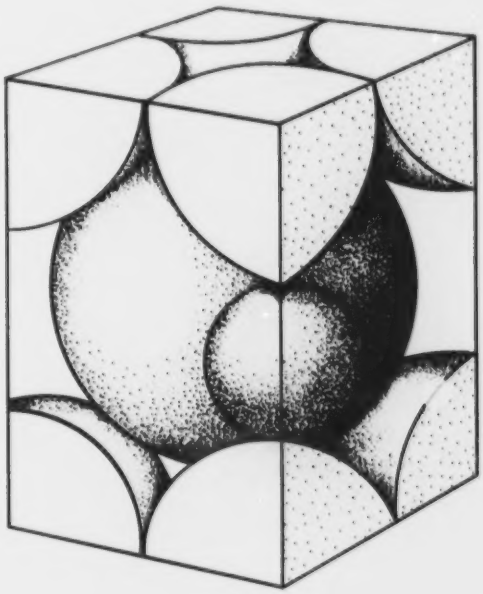
At high temperatures, iron forms a face-centered cubic cell:



Crystal Structure of Steel



Iron



Steel

The carbon atom fits in the holes of the face-centered cubic structure at high temperatures, but it does not fit in the body-centered cubic structure at normal temperatures. The presence of the carbon atom distorts the crystal. This causes steel to become hard.

LESSON
Supply & Demand

HAVE YOU EVER WONDERED? ***Why are metals useful for so many purposes?***

All of the Earth's basic elements known today can be broadly classified as either metals, nonmetals, or metalloids. The metals, which make up the bulk of elements known to us, are those elements which tend to lose electrons easily in the presence of other elements.

Metal atoms form a lattice structure in which electrons are readily passed back and forth among atoms. Each metal atom is bonded to other atoms around it by a surrounding "sea" of electrons. This type of bond is called a metallic bond. Metallic bonding gives metals the property of **malleability** (the ability to be shaped without breaking) because atoms can slide past each other and yet remain bonded. The mobility of electrons in a metallic bond causes metals to have high electrical and thermal conductivity. Most metals are reducing agents; they react with acids but usually not with bases.

The nonmetals are those elements which tend to accept electrons in the presence of other elements. In a nonmetallic solid, electrons do not readily move between atoms. This lack of electron mobility causes nonmetals to be brittle. An example of a nonmetal is carbon.

Metalloids have properties that are intermediate to metals and nonmetals. For instance, their electrical conductivity is higher than nonmetals but lower than metals; they are very useful as semiconductors. Silicon is a metalloid used extensively in computer circuitry.

Transition Metals

The large group of elements classified as metals can be divided into three sub-groups, the alkali metals, alkaline earth metals, and transition metals. Alkali metals, such as sodium, and alkaline earth metals, such as calcium, may not seem like metals to us, but actually they are strong metals since they lose electrons very easily. It is the transition metals, though, that have properties usually associated with metals: strength, hardness, malleability and **ductility** (a measure of the ability to undergo a change in shape without rupturing). Many have high melting temperatures. Iron, copper, gold, and zinc are examples of transition metals.

Iron: The Basic Ingredient of Steel

Iron, a transition metal and one of the most common elements on earth, is the basic ingredient of steel. Steel is a solid mixture of iron with a low percentage of carbon, less than two percent. (Cast iron, another important product from the element iron, contains two to four percent carbon.)

According to the International Iron and Steel Institute, world consumption of finished steel in 1991 was 628 million metric tons, comprised of 304 million metric tons of recycled scrap steel and 324 million metric tons of new steel. Recyclable scrap has been supplying more and more steel as the world population grows and the demand for steel increases. Consumption of aluminum and copper, the next two most widely used metals, was approximately 18 million metric tons (aluminum) and 11 million metric tons (copper) in 1991 (U.S. Bureau of Mines).

Iron is always found in nature as a chemical compound, usually with oxygen, carbon, sulfur and silicon. To make steel, iron and steel scrap (old steel) are melted, impurities are removed or their levels adjusted, and other elements may be added. The molten steel is cooled and shaped into a variety of products.

Alloys of Steel

An **alloy** is a mixture of two or more elements or compounds, at least one of which is a metal. Steel and cast iron are alloys of iron and carbon; iron is the **base metal** and carbon is the **alloying element**. All steel contains carbon, a nonmetal. Many steels contain other alloying elements, too. Most of these are transition metals. Manganese, nickel, chromium, molybdenum, and tungsten are important alloying elements of steel. Other transition metals used in steel are vanadium, cobalt, copper, aluminum, lead, titanium, and columbium. Nitrogen, phosphorous and boron are examples of nonmetals occasionally added to steel. Silicon is a metalloid often added to steel.

The properties of an alloy are different from the base metal. A pure iron knife blade would become dull the first time it was used because pure iron is relatively soft. By adding alloying elements, hardness, strength and durability can be improved. Alloys are generally harder and more fusible (easily melted) than pure metals. They are often less malleable and less ductile than pure metals. Alloying elements have these effects because of the manner in which the atoms fit into the crystal structure of iron.

For example, at high temperatures carbon atoms fit into the empty spaces in the iron lattice. As the steel cools, the lattice structure changes and the carbon atoms no longer fit. This distorts the lattice, interfering with the ability of the iron atoms to slide back and forth past each other. The lattice is held more firmly in position, and the steel becomes hard. In some types of steel the carbon precipitates out into small particles of cementite (Fe_3C) dispersed throughout the steel. (Imagine a mixture of salt and pepper; steel is the salt and grains of Fe_3C are the pepper.) This also causes the steel to be hard. The degree of hardness can be regulated by controlling the amount of carbon and the cooling rate.

Corrosion Resistance

Many metals exist in nature in the combined state, usually as oxides, sulfides, carbonates, or silicates. In these combined states, the energies of the metals are lower and the compounds are stable. When we purify metals, we force them into a higher energy, less stable state, and consequently there is a tendency for the metal to react chemically with the environment to form compounds, a process called corrosion. For example, iron often occurs in nature as iron oxide, Fe_2O_3. Once purified to metallic iron, it tends to return to its natural state and is easily oxidized in the presence of moisture and oxygen to form iron oxide, or rust.

This tendency of iron to return to its oxide can be prevented or delayed by adding certain elements to steel. A typical stainless steel, for instance, is 19 percent chromium, 10 percent nickel, a trace of carbon, and the remainder iron. Chromium, nickel, and carbon are the alloying elements; iron is the base metal. Stainless steel is highly corrosion resistant. Titanium is another alloying element which imparts corrosion resistance to steel. It is used for stoves, refrigerators and other enameled products.

Coating the steel is another way to improve corrosion resistance. Many objects, such as car bumpers and toasters, are plated with nickel and/or chromium. Some steel food cans are given a coating of tin. Nails and pipes often are coated with zinc in the process of **galvanizing**.

Zinc is as easily oxidized in the atmosphere as iron. Zinc and steel by themselves would corrode at the same rate. When zinc is applied to steel, it reacts with the steel and oxygen, and corrodes. The corrosion product forms a protective layer on the steel, reducing exposure of the steel to the environment. The zinc is "sacrificed" to protect the steel.

Note that coatings and alloys are not the same thing, though alloys are sometimes used as coatings. For example, some steel items have a stainless steel coating.

ACTIVITY 1

Making an Alloy

Learning Outcomes

Students will be able to:

- predict the physical properties of alloy-like substances
- demonstrate that adding components to an alloy-like substance changes its physical properties
- describe and cite examples of how a change in one physical property affects other physical properties

Time

One class period

Safety Tips

Review the safe use of a toaster oven. Discourage students from tasting the food combinations.

Materials/Equipment

Cardboard (30 x 45 centimeter)
Corn starch
Flour (white)
Mini-marshmallows
Muffin cups (foil)
Oven (toaster, with baking tray)*
Oven mitts
Plaster of paris
Salt
Spatulas
Tape (clear plastic)

* *If a toaster oven is not available, create a double boiler using foil muffin cups, a large aluminum pie plate to hold water, and a hot plate. If a microwave oven is preferred, substitute paper drinking cups for the foil muffin cups.*

Procedure

1. Use the *Background: Student*, pages 5 and 6, to discuss the relationship between the chemical structure and physical properties of an alloy. Explain that iron is the basic ingredient of steel and alloying elements are added to it to alter the physical properties of steel.
2. Divide the class into lab groups and provide each group with 50 grams of mini-marshmallows, 2.5 grams each of corn starch, white flour, plaster of paris and salt, a 30 x 45 centimeter piece of cardboard, six foil muffin cups, a spatula and tape. Students will need access to a toaster oven and oven mitts. (See suggestions under *Materials/Equipment* if a toaster oven is not available.)
3. Copy and provide to each student *Activity 1: Student*, pages 9 and 10. Point out that in this activity students will be simulating making an alloy; a true alloy always contains metal.
4. Review the steps of the activity. Demonstrate melting and stirring marshmallow in a foil muffin cup so students will understand at what point they should take the marshmallow out of the oven. Instruct lab groups to proceed with the activity.

Collecting and Analyzing Data

1. Direct the students to examine each of the cooled mixtures for luster, hardness, ductility and malleability, and rate these properties compared to the cooled marshmallow using the scale on page 10.
2. Ask students to observe what happened to malleability as hardness increased in the mixtures and record observations on the chart "Rating Properties of Alloy-like Mixtures," page 10. (Malleability will decrease as hardness increases.) Encourage them to cite other examples of how a change in one property effected a change in another property.

Drawing Conclusions

Q1: *In this activity, the added ingredients made up 20 percent of the total weight of the marshmallow mixture. How would increasing the proportions of the added ingredients to 50 percent affect the physical properties of the marshmallow mixtures? Why is it important for chemists to know the exact proportions of metals and minerals in the steel?*

A1: Increasing the proportions of added materials from 20 to 50 percent would continue to increase the intensity of some physical properties of the mixture. For instance, the mixture may continue to get harder, even to the point of brittleness, while losing malleability. It is important for chemists to know the exact proportions of minerals and metals in the steel to obtain the correct combination of hardness and malleability for a particular application.

Q2: *What are some chemical and physical properties that must be considered when supplying steel to the construction industry? Dinnerware and cookware manufacturers? Aviation industry?*

A2: Properties of steel that are desirable for construction are strength and durability; for dinnerware and cookware (stainless steel), smoothness and corrosion resistance; for airplane parts, heat resistance and durability.

ACTIVITY 1
Making an Alloy

Procedure

1. In this activity, you will be working in lab groups to understand how the physical properties of steel (mini-marshmallows) are affected when you add alloying elements (corn starch, flour, salt, or plaster of paris). You will need:
   - Cardboard (30 x 45 centimeter)
   - 2.5 grams each of corn starch, flour, plaster of paris, and salt
   - 50 grams mini-marshmallows
   - 6 muffin cups (foil)
   - Oven (toaster with baking tray)
   - Oven mitt
   - Spatula
   - Tape

Safety Tips

Use oven mitts when handling the tray of melted marshmallow. Do not taste the food combinations. Wear goggles, gloves, and an apron.

2. **Preparations**
   a) On the cardboard, make a grid with five sections. Each section must be large enough to hold a flattened (open) muffin cup to test the size.
   b) Label the sections as follows:
      - Control (marshmallow only)
      - Corn starch (marshmallow + corn starch)
      - Flour (marshmallow + flour)
      - Plaster (marshmallow + plaster of paris)
      - Salt (marshmallow + salt)
3. **Alloying Elements**
   a) Place ten grams of marshmallow in each of five muffin cups. Set the muffin cups on a baking tray and place in a warm oven (150 °C) for two to three minutes. Watch the marshmallow closely. Do not allow the marshmallow to turn brown.
   b) Using the oven mitt, remove the softened marshmallow from the oven. The marshmallow must be soft enough to stir without lumps.
   c) Place a muffin cup with marshmallow in each of the sections on the cardboard grid. Carefully open up the foil and tape the edges to the cardboard. Leave the marshmallow in the center.
   d) With a spatula, mix 2.5 grams of an "alloying element" (corn starch) into the "steel" (marshmallow) in the appropriate section of the grid. Work quickly so the marshmallow does not harden before you finish this step. Wipe the spatula clean.
   e) Repeat d) for the other "alloying elements" (flour, plaster of paris, and salt).
   f) Allow the marshmallow mixtures to cool. Conduct tests for luster, hardness, ductility, and malleability (see "Collecting and Analyzing Data").

Collecting and Analyzing Data

1. Refer to the chart "Scale for Determining Physical Properties of Melted and Cooled Marshmallow Mixtures," page 10. The control has been assigned a rating of 3 for each property (luster, hardness, ductility and malleability).

   Examine the melted and cooled marshmallow mixtures and compare them to the control. Rate the properties of the mixtures using these criteria:
   - Test for luster by visual observation.
   - Test for hardness by making an indentation with your fingernail.
   - Test for ductility by stretching a corner of the sample into a wire shape.
   - Test for malleability by forming the sample into a cube shape.

   Record your ratings in the chart "Rating Properties of Alloy-like Mixtures," page 10.
2. Observe what happened to malleability as hardness increased in the mixtures. Give other examples of how a change in one property effected a change in another property.

Scale for Determining Physical Properties of Melted and Cooled Marshmallow Mixtures

The control (marshmallow only) is assigned a rating of 3.							
LUSTER	dull	1	2	3	4	5	bright, lustrous
HARDNESS	soft	1	2	3	4	5	hard
DUCTILITY	ductile, easy to stretch	1	2	3	4	5	difficult to stretch
MALLEABILITY	malleable, easy to mold	1	2	3	4	5	stiff

Rating of Properties of Alloy-like Mixtures

Refer to the scale above. Compare the marshmallow mixtures to the control (3) and assign a rating (1–5) for each property — luster, hardness, ductility, and malleability.

MIXTURE	LUSTER	HARDNESS	DUCTILITY	MALLEABILITY
Corn starch				
Flour				
Plaster of paris				
Salt				

Drawing Conclusions

1. In this activity, the added ingredients made up 20 percent of the total weight of the marshmallow mixture. How would increasing the proportions of the added materials to 50 percent affect the physical properties of the marshmallow mixtures?
2. What are some chemical and physical properties that must be considered when supplying steel to the construction industry? Dinnerware and cookware manufacturers? Aviation industry?

ACTIVITY 2

Nails in Solution

Learning Outcomes

Students will be able to:

- classify steel and galvanized steel according to reactions to acid, base, and salt solutions
- construct formulas to represent the reactions
- explain the chemical process of corrosion and how it can be used to make galvanized steel

Time

Two class periods

Safety Tips

Describe safe handling procedures for each of the caustic and acidic solutions listed in *Materials/Equipment*. If a solution contacts skin or clothing, flush immediately with water. Students must wear goggles, gloves, and aprons.

Materials/Equipment

Beakers (100-mL)

Hand lens

Nails (non-coated steel and galvanized steel, five centimeters)

Paper towels

Petri dishes

Solutions:

distilled water

0.1 M HCl	(9 mL concentrated hydrochloric acid mixed in 1 liter water)
1 M NaOH	(40 grams sodium hydroxide mixed in 1 liter water)
0.5 M NaCl	(29 grams sodium chloride mixed in 1 liter water)

Tongs or forceps

Procedure

1. Use the *Background: Student*, pages 5 and 6, to discuss the properties of transition metals and the concept of galvanizing as one means of providing resistance to corrosion of steel. Refer to a general Chemistry text to review acid/base reactions and writing formulas.
2. Divide the class into lab groups. Provide each group with ten 100-mL beakers, ten petri dishes, five non-coated steel nails, five galvanized steel nails, a hand lens, tongs or forceps, and 50 mL of each solution.
3. Copy and distribute to each student *Activity 2: Student*, pages 13 and 14. Review the steps and instruct students to proceed with the activity.

Collecting and Analyzing Data

1. Instruct students to examine each nail for color and texture, and compare the nails in solutions with the control (nails exposed to air only). Ask students to observe and record the color of the solutions and add class data to the chart.
2. Combine class data on a chart and discuss different reactions and observations.

Drawing Conclusions

Q1: What happened to the steel and galvanized steel nails when soaked in the solutions? Construct formulas to represent the reactions.

A1: Steel nail

- Control (air only): no reaction. Iron will react with the oxygen in air to form rust, but the reaction is very slow unless water is present.
- HCl: bubbles of hydrogen gas can be seen immediately.

  $Fe^{2} + 2HCl \rightarrow FeCl_2 + H_2\uparrow$
- NaOH: no significant chemical reaction; most metals are reducing agents, not oxidizers. May see some cloudiness or particulate matter in the solution because NaOH solution is not stable. May see some "cleaning" action on the nails.
- NaCl: iron reacts with dissolved O_2 in the presence of salt. The solution will appear reddish and the nail rusty.

  $4Fe^{3+} + 3O_2 \rightarrow 2Fe_2O_3$
- Water: iron reacts with dissolved O_2 in the presence of water. The solution will appear reddish and the nail rusty.

  $2Fe^{3+} + 3H_2O \rightarrow Fe_2O_3 + 3H_2\uparrow$

Galvanized steel nail

- Control (air only): no reaction.
- HCl: hydrogen bubbles can be seen immediately; more vigorous reaction than steel nail.

  $Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$

  NaOH: no significant chemical reaction; most metals are reducing agents, not oxidizers. May see some cloudiness or particulate matter in the solution because NaOH solution is not stable. May see some "cleaning" action on the nails.
- NaCl: little or no reaction.
- Water: little or no reaction.

Q2: How would each of the reactions be affected if you were to deeply scratch the nails before soaking?

A2: Scratching increases surface area, so reactions would proceed more quickly. Regarding the galvanized steel nails, scratching damages the zinc coating, exposing the underlying steel to the solution. The underlying steel would then have an opportunity to react with dissolved oxygen in water or salt solution.

ACTIVITY 2
Nails in Solution

Procedure

1. In this activity, you will work in lab groups to test the reaction of steel and galvanized steel to acid, base, and salt solutions. You will need:
   - 10 beakers (100-mL)
   - 1 hand lens
   - 5 nails (non-coated steel)
   - 5 nails (galvanized steel)
   - Paper towels
   - 10 petri dishes
   - 50-mL of each of the following solutions:
     0.1 M HCl (hydrochloric acid)
     1 M NaOH (sodium hydroxide)
     0.5 M NaCl (sodium chloride)
     distilled water
   - 1 tongs or forceps

Safety Tips

Use safe techniques for handling each of the caustic and acidic solutions. If a solution contacts skin or clothing, flush immediately with water. Wear goggles, gloves, and aprons.

2. **Examine nails and solutions.**
   a) Examine a steel nail and a galvanized steel nail for color and texture. Use the hand lens to get a close look at the surface. Record your observations in the chart "Observations Before Soaking," page 14.
   b) Observe and record the color of the solutions in the chart "Observations Before Soaking."

3. **Place the nails in solution.**
   a) Place a steel nail and a galvanized steel nail in two separate beakers. Cover the beakers with petri dishes. Label the beakers with the type of nail and "control."
   b) Place a steel nail and a galvanized steel nail in two separate beakers. Carefully pour 50-mL of 0.1 M HCl into each beaker. Cover the beakers with petri dishes. Label the beakers for type of nail and solution.
   c) Repeat step b) for each of the other solutions.

4. **Observe after five minutes.**
   Record observations of the nails and solutions in the top half of the chart "Appearance of Nails and Solutions After Soaking," page 14.

5. **Remove from solution after one day.**
   a) Use the tongs to carefully remove the nails from the beakers. Be careful not to touch the nails or solutions with your bare hands. Save the solutions for observation.
   b) Rinse the nails with distilled water and place them on paper towels to dry. Label the paper towels with the type of nail and solution.

Collecting and Analyzing Data

1. Examine each nail for color and texture. Compare the nails in solutions with the control (nails exposed to air only). Record your observations in the bottom half of the chart "Appearance of Nails and Solutions After Soaking." Observe and record the color of the solutions in the same chart.
2. Participate in a class discussion on the different reactions and observations.

Drawing Conclusions

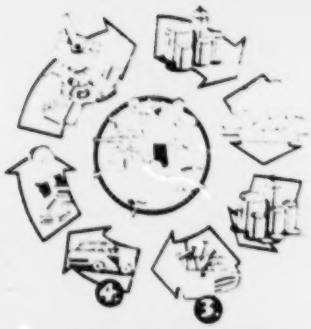
1. What happened to the steel and galvanized steel nails when soaked in the solutions? Construct formulas to represent the reactions.
2. How would each of the reactions be affected if you were to deeply scratch the nails before soaking?

Observations Before Soaking

NAILS: Steel	
Galvanized steel	
SOLUTIONS: HCl	
NaOH	
NaCl	
Distilled water	

Appearance of Nails and Solutions After Soaking

NAIL	CONTROL (AIR ONLY)	HCl	NaOH	NaCl	DISTILLED WATER
After five minutes					
Steel					
Galvanized steel					
After one day					
Steel					
Galvanized steel					



LESSON

Collect & Haul

In this lesson, students will discover the role of transition metals in the manufacture of cars and select steel objects. This will be achieved through an understanding of automakers' efforts to design automobiles for reuse and recycling, and by performing physical tests on steel objects used for packaging and transporting materials.

Key Terms

Key terms are highlighted in the *Background: Student* with definitions provided in the Glossary.

disassembly **fluff** **scrap**
ferrous **nonferrous** **transition metals**

Motivation

- Ask students to determine the number of cars in their community and calculate the mass of material from cars entering the waste stream per year. Have them make the following assumptions: every household owns two cars; the average mass of a car is 1136 kilograms; and half the cars in the community are discarded each year.
- Visit an automobile scrap yard. Discuss the processes used for dismantling and moving car parts for reuse or recycling.

Demonstration

Find a used appliance, phone, or typewriter. Either as a class or in small groups, disassemble the item, keeping track of the time it takes to sort and prepare the parts so that each category has only one type of material (e.g., steel, copper, rigid plastic). Calculate the time it would take to disassemble 30 million of that same item. Discuss the advantages and disadvantages of disassembling this item for reuse or recycling. (See the activity *Metals For Toasters* in the ***Cycles for Science*** *General Science and Earth Science* curriculum supplement.)

Content Development

Copy onto transparencies or use as handouts the figures *Average Composition of a U.S. Built Car* and *Example of Magnetic Equipment Used in Automobile Shredding Scrap Yards*, pages 17 and 18. Copy and distribute to each student the *Background: Student*, pages 19 and 20. Use the figures and background reading as references in discussing transition metals in cars, the collection of ferrous metals from shredded cars, and complete car recycling. See *Appendix: Bibliography* for a list of reference papers on car recycling.

Learning Outcomes

Activity 3. Recyclable Cars

Students will be able to:

- describe the collection process for recovering automotive parts for reuse and recycling
- identify car parts by their composition and properties
- evaluate from a citizen's point of view the role of the consumer, carmaker and government in seeking solutions to car recycling

Activity 4. Scratch or Dent

Students will be able to:

- form a model of the metallic bonding and alloying of two or more metals
- predict the arrangement of atoms and electrons in the metallic structure
- describe the physical properties and function of steel objects used for packaging and transporting materials

Extension

The following activity expands on concepts introduced in this lesson.

WHERE DO OLD CARS GO?

Research locations in your community where cars are disassembled for reuse or recycling. Assign groups of students to visit the facility or arrange a phone interview with the manager or employee in charge. Instruct each group to collect responses to the following questions:

- What types of car parts do you remove to resell?
- What car parts are recycled?
- What are the markets for the recyclable car parts?
- What car part is the most challenging to recover for reuse or recycling?

Design a chart including each question with group responses listed. Review the data collected and compare and contrast the responses.

Independent Study

- Research further efforts by carmakers to produce environmentally friendly cars. Discuss efforts to remove cadmium and asbestos from paint and insulation, and chlorofluorocarbons (CFCs) from air conditioning systems. Contact your local electric company for information on handling CFCs in appliances.
- Produce a model of an electric car and discuss how the metal alloy requirements will be the same or different than a gasoline-powered car. Contact local colleges with engineering schools for information on a national competition for designing electric cars.

Evaluation "Test Your Knowledge"

Evaluate student learning of the concepts introduced in this lesson. "Test Your Knowledge" suggestions:

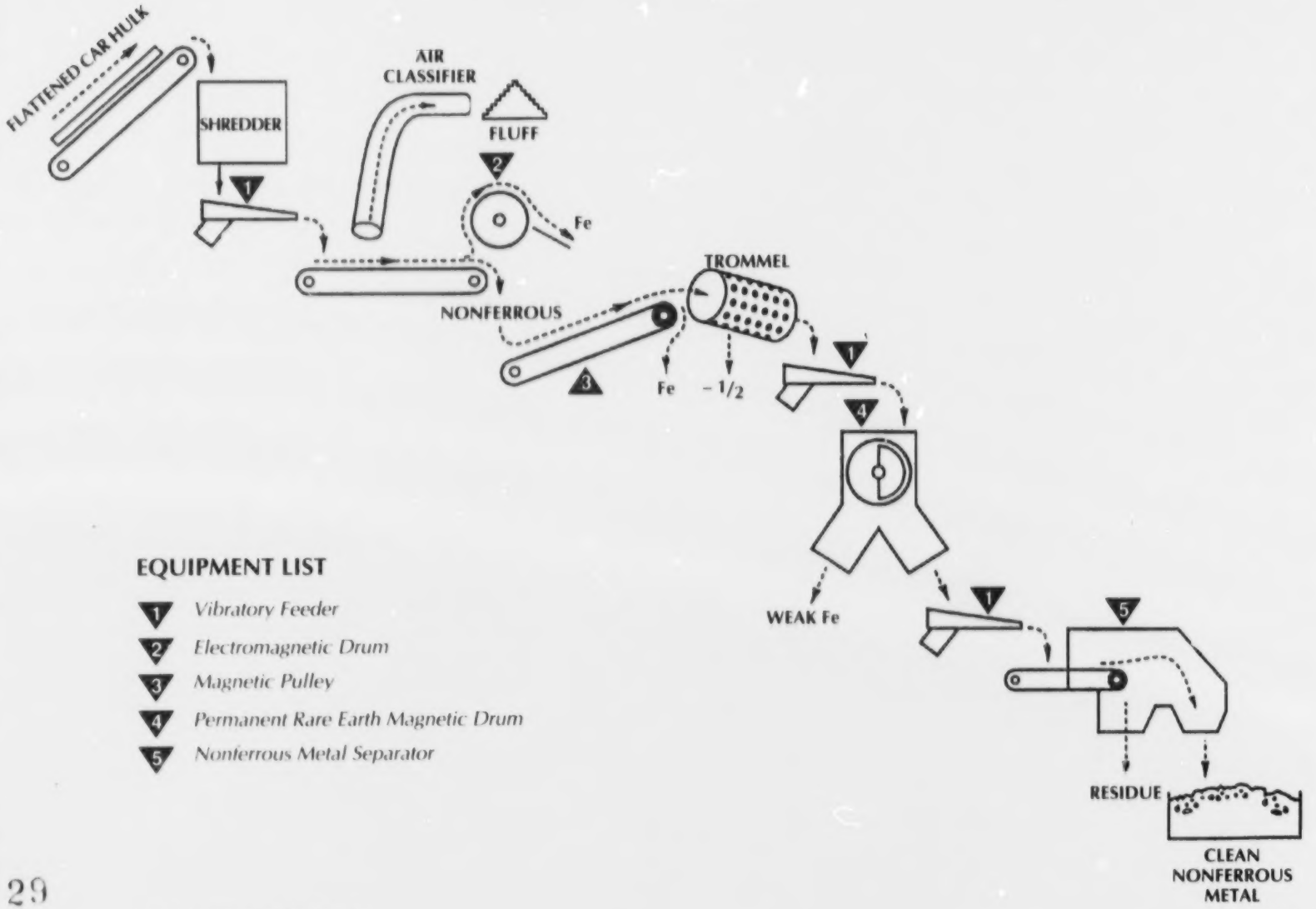
- Create a concept map for one car part by listing metal alloy(s), transition metals and other materials; for each metal or material, describe the physical properties.
- Draw a car, locate and identify four car parts, and for each part indicate if it can be reused or recycled.
- Use the key terms to write an advertisement for the products or services of a local scrap dealer, broker or recycler.

Average Composition of a U.S. Built Car

MATERIAL	MASS (kg)	CHEMICAL COMPOSITION	COMMON PROPERTIES
STEEL			
• conventional (plain carbon)	566	Fe, C, Mn	• range of strengths • heat resistance • can be bendable or rigid
• high strength (alloy steel)	106	Fe, C, alloys	
• stainless	15	Fe, Cr, Ni	
• other	24	Fe, C, alloys	
IRON • cast iron	181	Fe, C	• hardness, brittleness • heat resistance • is cast into the desired shape
ALUMINUM	72	Al	• low density • low strength • good electrical properties
COPPER	21	Cu	• high electrical conductivity • high thermal conductivity • high corrosion resistance
ZINC DIE CAST	9	Zn	• corrosion resistance
POWDER METAL	10	assorted metals	• a unique combination of properties
RUBBER	58	hydrocarbons	• durability
PLASTICS	101	complex hydrocarbons	• light weight • limited strength
FLUIDS	76	petroleum and water based	• varies by fluid
OTHER MATERIALS • Glass • Magnesium • Ceramic • Other	40	Si, O Mg Al, Si, O, minerals	• varies by material

Source: S.S. Labana, "Recycling of Automobiles," Ford Motor Company, Dearborn, MI, 1990. Data compiled from production figures for Ford automobiles.

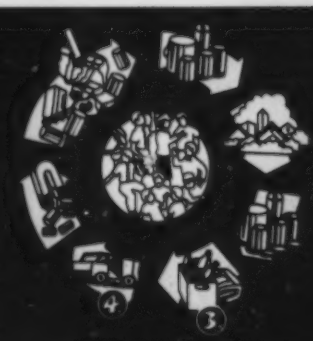
Example of Magnetic Equipment Used in Automobile Shredding Scrap Yards



EQUIPMENT LIST

1. *Vibratory Feeder*
2. *Electromagnetic Drum*
3. *Magnetic Pulley*
4. *Permanent Rare Earth Magnetic Drum*
5. *Nonferrous Metal Separator*

Source: Eriez Magnetics, Erie, PA.



LESSON
Collect & Haul

HAVE YOU EVER WONDERED? ***How many millions of cars are scrapped each year, and what happens to the metals?***

According to a recent article published by the Institute of Scrap Recycling Industries ("Total Car Recycling: Just a Green Dream?" *Scrap Processing and Recycling*, Sept. 10, 1992), nearly 30 million cars throughout the world are recycled every year. Ninety-four percent of the automobiles discarded in the United States are dismantled for reuse or recycling, with 75 percent of the content ultimately recycled ("Carmakers Say Recycling Can Mold Positive Image," *Automotive News*, Nov. 15, 1993). Steel is America's most recycled material, and cars are a major source of **scrap steel**.

Although the steel in cars is highly recycled, cars contain many materials besides steel which currently are not being recycled. Automakers continue working to achieve something closer to recycling perfection. Ford, General Motors and Chrysler, for instance, have formed the Vehicle Recycling Partnership, which includes participants from the scrap recycling, parts supply, plastic, and dismantling industries, as well as university and government research labs. Saturn, another carmaker focusing on recycling cars, believes that recycling is growing in importance to consumers, though it does not outrank quality, safety, reliability and durability when selecting a car. The U.S. Council for Automotive Research plans to open a research center in Highland Park, Michigan in 1994 to develop automotive recycling technology.

Transition Metals in Cars

The composition of a typical U.S. passenger car built in 1990 is approximately 711 kilograms of steel, 181 kilograms of iron, 101 kilograms of plastic, 76 kilograms of fluids, 72 kilograms of aluminum, 58 kilograms of rubber, 21 kilograms of copper, and 59 kilograms of other materials (S.S. Labana, Ford Motor Company). Transition metals — the elements located more or less in the center of the periodic table — comprise the largest percentage of materials used in car manufacturing, and are most easily recovered for recycling. Iron, aluminum and copper are transition metals; steel is an alloy of iron and carbon. Other transition elements are often added to steel to give it specific properties.

The Recycling Process

When an automobile is hauled to the scrap yard, it is first drained of all its fluids and stripped of all its reusable parts. Parts which are commonly reconditioned and reused include the battery, radiator, electric motor, transmission, catalytic converter, engine block, and windshield.

Following the stripping operation, the hulk (car body) is processed by shredding. **Ferrous** scrap (iron and steel) is collected magnetically from the shredded material. **Nonferrous** scrap (metals not containing iron) is collected mechanically and by other means. Once collected, the metals can be recycled into new metal products.

The 20 to 30 percent of the car that is left is commonly known in the industry as shredder **fluff**. Fluff contains primarily nonmetallic materials such as plastics, glass, rubber, carpet, and dirt. Carmakers are working to develop recycling methods for the plastic, but currently most of the fluff is either hauled to a landfill or incinerated.

Recycling Cars Already Built

It is not easy to recycle cars that are already built, or are currently being built, because these cars were not designed for **disassembly**, reuse, or recycling. The exception is that steel is easily removed from cars for recycling, with a recycling rate exceeding 90%. Many car parts contain two or more materials that are difficult to separate. For instance, many car parts contain more than one plastic; carmakers reportedly draw from a spectrum of more than 120 different thermoplastics and thermosets. This impedes recycling because plastics must be separated by type before they can be recycled. Other car parts may have different materials glued together with a strong adhesive; an example is the insulation and fabric lining the inside of the car. Airbags pose a special problem for recycling; the pressurized gas which causes the airbag to inflate can also cause an explosion in the automobile shredder.

Carmakers are promoting several options in dealing with the collection process for recycling cars already built. European automakers, who have been under pressure from stringent governmental measures and environmental groups, have already developed systems for recycling existing cars. The following information is from the article "Total Car Recycling, Just a Green Dream?" *Scrap Processing and Recycling*, 1992.

"BMW AG (Munich, Germany), for example, has advanced a 'cascade' model of car recycling procedures which defines the hierarchy of preferred uses: reuse of parts as spares or reconditioned replacements; direct material recycling; chemical (indirect) recycling; and energy recovery. Chemical recycling approaches include hydrolysis, glycolysis, pyrolysis, and hydrogenation [these are chemical processes used to break down plastics].

"Nissan Motor Co. Ltd. (Tokyo) is recycling polypropylene (PP) bumpers, using a technology that removes paint from the bumpers. The recovered plastic is used to make air ducts, rear bumpers, foot rests, and transport pallets.

"Mercedes-Benz AG's (Stuttgart, Germany) proposed car recycling plan involves a metallurgical system for collecting the recyclable materials. Under the Mercedes plan, after all fluids are drained from scrapped cars, engines would be pulled and either reconditioned for resale or shredded alone. All batteries, catalytic converters, and copper-bearing wires, motors and cables also would be taken out, and then all recyclable plastic parts would be removed. The remaining hulk, including the tires and some plastic, would be baled and fed into a natural-gas-fired steel smelter."

Designing for the Future

Carmakers agree that it is easier to build recyclability into new cars than to play a game of catch-up with old vehicles. Most auto recycling is still in the design stage and is based on two different but overlapping concepts, design for recycling and design for disassembly. Both concepts encompass such recycling related efforts as:

- Easing the removal of automotive parts.
- Eliminating nonrecyclable or hazardous materials.
- Reducing the variety of plastics used in parts.
- Avoiding parts that combine incompatible materials, such as plastics and metals, or making sure incompatible materials are easily separated from each other.
- Making plastic parts easier to identify by resin type.

Improving the recyclability of cars is a global challenge — and goal — for the auto industry and every automobile manufacturer. Car recycling is an intricate balancing act between motorist, industry, and government. All parties must work cooperatively on solutions and each must pay part of the cost. Although virtually all the steel and many other metals are highly recycled from cars, the goal is to achieve optimum ecological benefits at an acceptable cost.

Thermoplastics are resins or plastics capable of softening when heated and hardening again when cooled. Thermosets are resins or plastics capable of becoming permanently rigid when heated or cured.

ACTIVITY 3

Recyclable Cars

Learning Outcomes

Students will be able to:

- describe the collection process for recovering automotive parts for reuse and recycling
- identify car parts by their composition and properties
- evaluate from a citizen's point of view the role of the consumer, carmaker, and government in seeking solutions to car recycling

Time

One to two class periods

Safety Tips

Review safety procedures for examining a car. Before allowing students to examine a car, check to see that the keys are not in the ignition and that the car is securely parked. Make sure students understand the following:

DO NOT get under the car, unscrew any caps or touch any fluids. If fluids contact your skin or clothing, flush with water immediately.

Make sure the hood is securely supported before looking under it. Be sure all engine parts and the exhaust system are cool before touching them.

Do not remove any car parts from the car.

Materials/Equipment

Cars
Car parts (actual or photo, suggestions:
copper wiring, transmission, exhaust pipe, hub cap, radiator, spark plugs)
Magnets
Optional Car repair book from the library

Figures/Tables

Scheme for an Automobile, page 23

Composition of Select Car Parts, page 24

Procedure

1. Copy onto transparencies and provide as handouts the *Scheme for an Automobile* and *Composition of Select Car Parts*. As you show the figure and table, discuss the location, function and material composition of various car parts, and the chemical composition and properties of each material. Display actual or photo examples of each part discussed.
2. Use the *Background: Student* on pages 19 and 20 to introduce the concept of car recycling. Discuss the successes and problems of collecting automotive parts for recycling. *Optional:* Relate the discussion on recycling to the disassembly activity suggested under *Demonstration* on page 15.
3. Divide the class into lab groups. If possible, include in each lab group at least one student who is knowledgeable about cars. Provide a magnet for each group. Assign each group one of the following sections in their designated car:
   - *Under the hood* includes the engine, battery, radiator, hoses, and any other car parts under the hood.
   - *Car exterior* includes the car body, tires, windows, exterior mirrors, and any other car parts on the outside of the car.
   - *Car interior* includes the seats, steering wheel, gear shift, dashboard, floor coverings, and any other car parts inside the car.
4. Copy and distribute to each student *Activity 3: Student*, pages 25 and 26. Review the steps for surveying a car and instruct students to proceed with the activity.
5. Assist students in describing the conditions the car parts are expected to withstand, by referring to *Average Composition of a U.S. Built Car*, page 17.

Collecting and Analyzing Data

1. Ask each group to describe the car parts observed. In a large chart, compile a class list of parts and materials. Compare the list with data in *Scheme for an Automobile* and *Composition of Select Car Parts*.

   Suggested extension: Compare the proportions of materials observed with *Average Composition of a U.S. Built Car*, page 17.

2. Instruct students to predict for each selected car part whether it would be reused or recycled after shredding, or if it would be landfilled. Lead a class discussion, using the Teacher Answer Key below, to determine the validity of the various predictions.

TEACHER ANSWER KEY FOR REUSE, RECYCLE OR LANDFILL?

These lists may change as new technologies are developed.

Reuse The following car parts are commonly removed (whole) for reconditioning and resale:

- Radiators
- Battery
- Gas tank
- Tires (retread)
- Catalytic converter
- Other useable parts such as windshields, transmissions, steering wheels and column

Contact your local used auto parts dealer to verify other parts listed by students.

Recycle The following car parts (dismantled) and materials are currently recycled:

- Iron and steel
- Copper wiring
- Aluminum and other metals
- Batteries
- Catalytic converters
- CFCs
- Some fluids
- Some plastics

Landfill The following car materials are currently non-recoverable for reuse or recycling.

- Some plastics
- Rubber
- Some tires
- Some fluids
- Sealers
- Carpet
- Seats
- Some glass

Drawing Conclusions

Q1: What are three concepts being considered by carmakers for improving disassembly of cars for reuse or recycling?

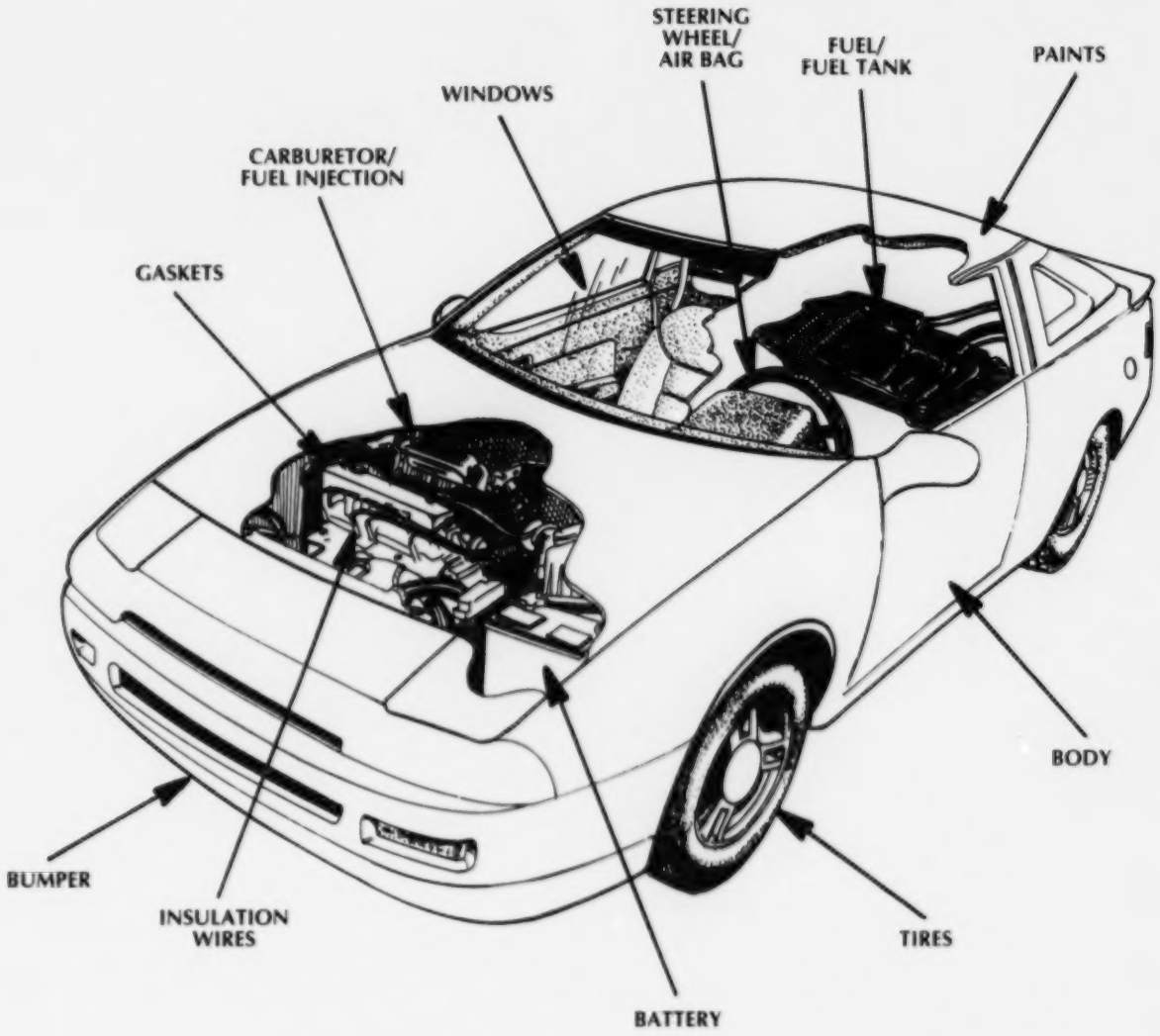
A1: Any three of the following:

- Easing the removal of automotive parts.
- Eliminating nonrecyclable or hazardous materials.
- Reducing the variety of plastics used in parts. (Carmakers reportedly draw from a spectrum of more than 120 different thermoplastics and thermosets.)
- Avoiding parts that combine incompatible (for recycling) materials, such as plastics and metals, or making sure incompatible materials are easily separated from each other.
- Making plastic parts easier to identify by resin type.

Q2: What type of collection process or alternative design would you suggest to increase the recyclability of a car?

A2: The reasoning by the student should focus on new collection processes (any creative concepts are acceptable) and designs which provide greater ability for a car to be disassembled for reuse or improved recycling of the shredded material, including the fluff.

Scheme for an Automobile



Composition of Select Car Parts

Materials listed are the primary materials typically found in that car part; materials may vary according to the manufacturer.

CAR PART	TYPICAL COMPOSITION
Battery	lead plates, acid, rubber, plastics
Body	steel or fiberglass
Bumper	nickel, chromium and steel, or plastic
Carburetor/fuel injector	carburetor (older model cars): lead, zinc, antimony, tin, copper fuel injector (newer model cars): brass, steel
Fuel/fuel tank	fuel: petroleum fuel tank: steel or plastic
Gasket	natural or synthetic rubber, cork, paper, and plastic pastes, or soft metallic materials such as lead and copper
Insulation wire	copper, plastics, rubber
Paint	acrylic resins (petroleum-based polymers)
Radiator	copper fins, brass tank (older model cars) aluminum fins, plastic tank (newer model cars)
Steering wheel/air bag	steering wheel and column: plastics, steel air bag (newer model cars): plastics, metals
Tire	natural and synthetic rubber, fabric (primarily rayon, nylon or polyester, sometimes with fiberglass or finely drawn steel), steel
Window	safety glass (two layers of glass with plastic in between)

Sources: *McGraw-Hill Encyclopedia of Science and Technology*, 1992; *World Book Encyclopedia*, 1994; Taylor, John, *How Cars Are Made*, Facts on File Publication: New York, 1987.

ACTIVITY 3
Recyclable Cars

Procedure

1. In this activity, you will be working in lab groups to complete a survey of the materials used in a car. You will need:
   - 1 or more magnets
   - *Scheme for an Automobile*, page 23
   - *Composition of Select Car Parts*, page 24

   Your teacher will assign your group to examine one of the following sections of a designated car:
   - *Under the hood* includes the engine, battery, radiator, hoses, and any other car parts under the hood.
   - *Car exterior* includes the car body, tires, windows, exterior mirrors, and any other car parts on the outside of the car.
   - *Car interior* includes the seats, steering wheel, gear shift, dashboard, floor coverings, and any other car parts inside the car.

Safety Tips

Do not get under the car, unscrew any caps or touch any fluids. If fluids contact your skin or clothing, flush with water immediately. Make sure the hood is securely supported before looking under it. Be sure the engine and the exhaust system are cool before touching them. Do not remove any car parts from the car. Wear goggles, gloves, and an apron.

2. Examine the car section assigned to your group and select five car parts to describe. You may choose parts shown in the figure *Scheme of an Automobile*, but you are not limited to those parts. Complete the chart "Car Survey: Car Parts, Materials and Properties" on page 26.

   a) List the material(s) in each car part (metal, plastic, ceramic, glass, rubber, or other). Use a magnet to determine whether the metals are ferrous (steel, cast iron, nickel) or nonferrous (aluminum, copper, zinc, chromium, and others).

   b) Briefly describe the conditions the car part is expected to withstand. For instance, does the car part have contact with heat or chemicals? Must the car part have good electrical conductivity? Is it subjected to stress and strain?

Collecting and Analyzing Data

1. Describe to the class the car parts that you examined. Your teacher will compile a class list of car parts and materials. Compare the class list with data in *Scheme for an Automobile* and *Composition of Select Car Parts*.
2. For each car part selected, predict whether it would be reused, recycled after shredding, or if it would be landfilled. Record your response in the chart "Reuse, Recycle or Landfill?" on page 26.

   Participate in a class discussion to determine whether predictions made by your group and others are valid. Refer to the *Background: Student*, pages 19 and 20, for assistance in analyzing the various predictions.

Drawing Conclusions

1. What are three design concepts being considered by carmakers for improving disassembly of cars for reuse or recycling?
2. What type of collection process or alternative design would you suggest to increase the recyclability of cars?

Car Survey: Car Parts, Materials and Properties

Check one: Under the hood ☐ Car exterior ☐ Car interior ☐		
CAR PART	**MATERIALS** *Parts may be made of one or more of ferrous metal, nonferrous metal, plastic, ceramic, glass, rubber, other.*	**PROPERTIES** *Briefly describe the conditions the car part is expected to withstand (heat, chemicals, stress and strain, etc.).*

Reuse, Recycle or Landfill?

For each car part selected, predict whether it could be reused, recycled after shredding, or if it must be landfilled.			
CAR PART	**REUSE**	**RECYCLE**	**LANDFILL**

ACTIVITY 4

Scratch or Dent

Learning Outcomes

Students will be able to:

- form a model of the metallic bonding and alloying of two or more metals
- predict the arrangement of atoms and electrons in the metallic structure
- describe the physical properties and function of steel objects used for packaging and transporting materials

Time

One class period

Safety Tips

Demonstrate puncturing and hammering techniques to avoid injury or property damage. Students must wear work gloves and goggles.

Materials/Equipment

Balls (ping pong and tennis)
Gloves (work)
Hammers
Hand lens
Marbles
Metal objects used for packaging (suggestions: food and beverage cans, paint cans, lids from jars, strapping)
Pliers
Screwdrivers
Shoebox (clear plastic)

Figures/Tables

Crystal Structure of Iron, page 3

Crystal Structure of Steel, page 4

Demonstration

1. Copy onto transparencies the figures *Crystal Structure of Iron* and *Crystal Structure of Steel*. As you show the transparencies, explain metallic bonding and how the crystal arrangement allows for making steel. For more information on the crystal structure of steel, refer to the *Background: Student*, page 6.
2. Demonstrate the concept of metallic bonding and alloying. Place tennis balls in a shoe box, packing them tightly to represent iron atoms in a crystal structure. Place ping pong balls in the spaces between the tennis balls to represent carbon, the major alloying element of steel. Place marbles in the tiny spaces between the tennis and ping pong balls, to represent other alloying elements, such as manganese, nickel, chromium, and molybdenum.
3. Make the demonstration available as a station for each student to rebuild the model. Refer students back to the *Background: Student*, page 6, or to a Chemistry text for more information on metallic bonding and the crystal structures of steel alloys.

Procedure

1. Describe the physical properties of steel; refer to the table *Average Composition of a U.S. Built Car*, page 17. Discuss the advantages of packaging and transporting materials using steel and other metals (i.e., maintain color and taste, low cost, non-reactive with liquid contents, resistant to crushing).
2. Assign students to lab groups. Provide each group with a hammer, two pairs of pliers, screwdriver, hand lens, and two metal objects.
3. Copy and distribute to each student *Activity 4: Student*, pages 29 and 30. Review the steps and instruct lab groups to perform the activity.

Collecting and Analyzing Data

1. Ask each group to list the physical properties of the two metal objects and describe how these properties apply to the metals used in containers for packaging and transporting materials.
2. Instruct students to draw a model of one of the metal objects showing the arrangement of atoms before and after a physical test.

Drawing Conclusions

Q1: How is the bonding of metals different from the covalent bonding of other materials?

A1: Metallic bonding is a "floating" bond in which electrons are easily shared. Covalent bonds are fixed. Metallic bonding and alloying of metals provides the wide range of properties found in metals.

Q2: What physical properties must be considered when manufacturing a steel container/lid for green beans? Paint?

A2: A steel food container for green beans must be strong enough to withstand scratches and dents during handling and bear the weight of other cans during shipping. Paint cans must be able to withstand tumbling when mixing colors, and must provide a lid which can be reopened many times while preventing the contents from drying out.

ACTIVITY 4
Scratch or Dent

Procedure

1. In this activity, you will work with your lab group to perform physical tests on metal objects. You will need:
   - 1 hammer
   - 2 pairs of pliers
   - Hand lens
   - 1 screw driver
   - 2 metal objects (e.g., food cans, beverage cans, paint cans, lids from jars, strapping)

Safety Tips

Exercise caution when puncturing and hammering metals. Wear goggles and work gloves.

2. Perform the following tests using the same amount of force on each metal object. Record your observations in the chart "Observations from Physical Tests."
   a) **Scratch test.** Use a screwdriver to scratch the metal. Examine the scratch under the hand lens and observe whether the metal was easy or difficult to scratch.
   b) **Puncture test.** Use a screwdriver to attempt to puncture the metal. Examine the site under the hand lens and observe whether the metal was easy or difficult to puncture.
   c) **Dent test.** Use the hammer to hit the metal object once. Examine the site under the hand lens to observe whether the metal was easy or difficult to dent.
   d) **Twist and bend test.** Use the pliers to firmly grasp two edges of the metal object, and attempt to twist and bend it. Observe whether the metal was easy or difficult to twist and bend.

Observations from Physical Tests

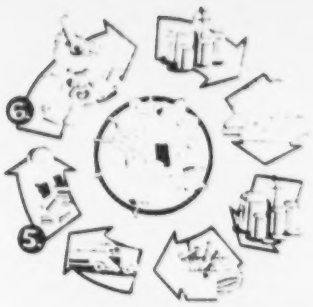
METAL OBJECT	TEST			
	Scratch	Puncture	Dent	Twist & Bend

Collecting and Analyzing Data

1. List the physical properties of the two metal objects and describe how these properties apply to the metal used in containers for packaging and transporting materials.
2. Draw a model of one of the metal objects showing the arrangement of atoms before and after a physical test.

Drawing Conclusions

1. How is the bonding of metals different from covalent bonding of other materials?
2. What physical properties must be considered when manufacturing a steel container/lid for green beans? Paint?



LESSON

Sort & Produce

In this lesson, students will understand how the properties of transition metals can be used to sort or extract the metals from a mixture and how the addition of alloying elements affects the melting points of metals.

Key Terms

Key terms are highlighted in the *Background: Student* with definitions provided in the *Glossary*.

basic oxygen furnace
electric arc furnace
ferromagnetic
flotation
integrated mill
mini-mill

Motivation

Brainstorm with students for five minutes and list items containing steel found at home, at school, and in the community. Ask teams of students to select one of these items and respond to the following questions:

- What physical properties are necessary for this item to function properly (e.g., heat resistance, strength, corrosion resistance)?
- What materials besides steel could have been used to make this product (e.g., wood, plastic, ceramics, other metals)? What advantages does steel have over other materials for making this product? Disadvantages?

Demonstration

Create a display "From Rock to Steel." Exhibit samples of the major natural resources used in making steel: iron ores (hematite, magnetite, and limonite), coal, and limestone.

Content Development

Prepare transparencies of *The Making of Steel* and *Steelmaking Furnaces*, pages 33 and 34. Copy and distribute to each student the *Background: Student*, pages 35 and 36. Refer to the transparencies as you discuss with the class the processes of steelmaking and sorting.

Learning Outcomes

Activity 5. Sorting Commingled Metals

Students will be able to:

- describe the properties of aluminum, iron, and lead
- identify metals in a mixture
- calculate the representative composition of metals extracted from a mixture

Activity 6. Melting Alloys

Students will be able to:

- observe the change in a metal from the solid to the liquid state
- identify differences in melting points of various alloys
- explain how the addition of alloying elements to a base metal may affect the melting point

Extension

The following activity expands on concepts introduced in this lesson.

SAVE ENERGY, RECYCLE?

Refer to *Did You Know? Steel Recycling* on page 50 to discuss the heat energy and raw materials saved through recycling scrap steel. Make an analogy of the savings (e.g., enough energy to light all the homes in your city for a year).

Have the class use this information to prepare a display including a chart and other visuals.

Assign groups of students one of the following items: newspaper, glass, plastic, or aluminum. Instruct each group to research the heat energy and natural resources saved through recycling their item; for information, contact a local solid waste management office or organizations listed under *Resources*, page 51. Ask students to prepare a display similar to the one for steel.

Share this information by setting up the displays in the school or by peer teaching the information to students in other grade levels.

Independent Study

- Visit a production facility and interview a staff chemist to learn about chemical reactions in the production process and quality control. Inquire about the use of recycled materials and efforts to increase efficiency and decrease waste in the production process.
- Visit a boat dock, construction site, or suspension bridge. Observe the types of metals used. Prepare a presentation on the conditions to which the metals are exposed (water, salt, atmosphere) and the properties of the metals that make them best suited for use in those conditions. Include examples of chemical reactions, such as the oxidation of metallic iron to iron oxide, that are likely to occur in those conditions.

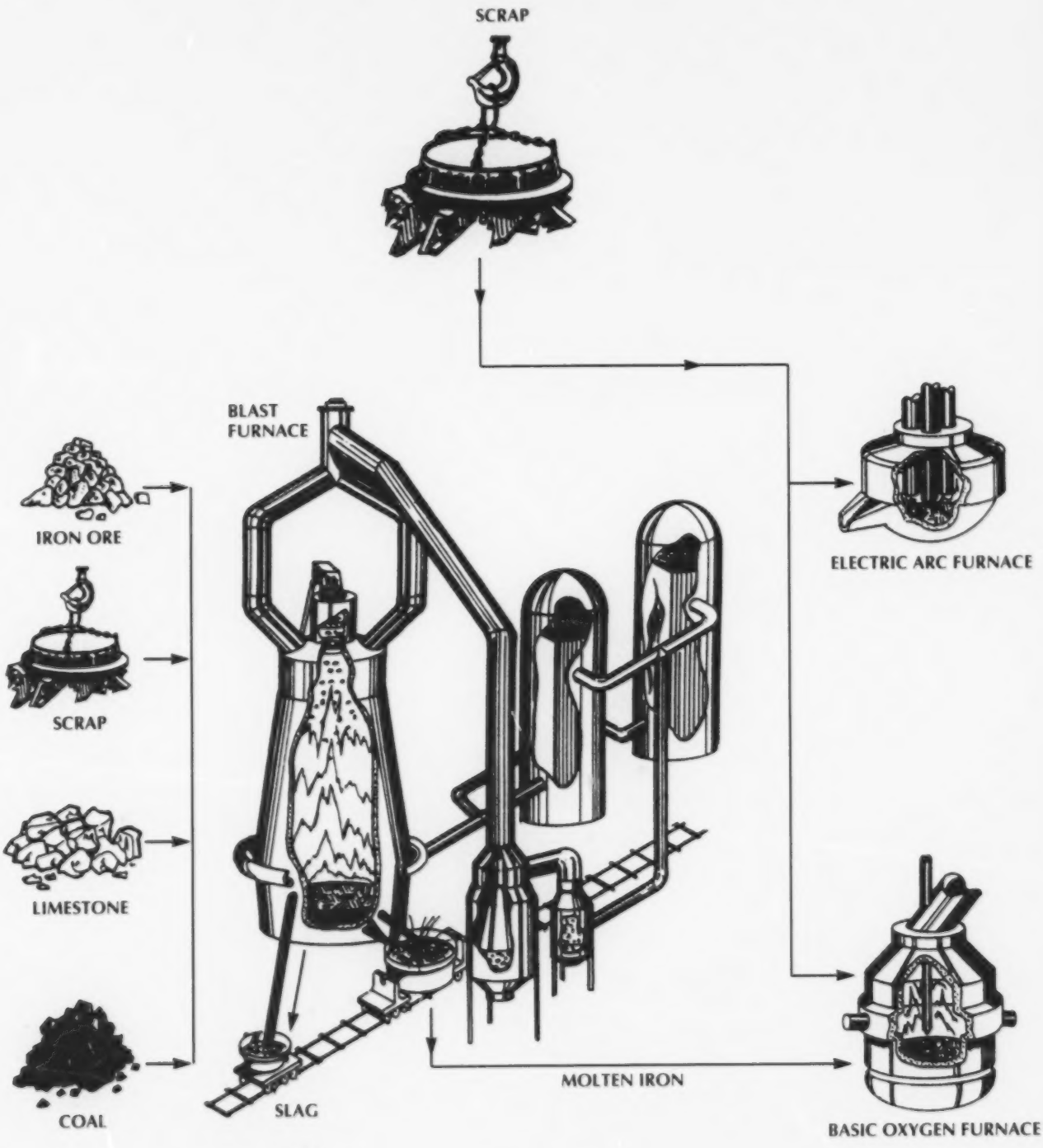
Evaluation "Test Your Knowledge"

Evaluate student learning of the concepts introduced in this lesson. "Test Your Knowledge" suggestions:

- Create a concept map of the steelmaking process.
- Describe a step-by-step process for separating commingled steel cans, aluminum cans, and glass jars for recycling.
- Use the key terms to write an article for the school paper.

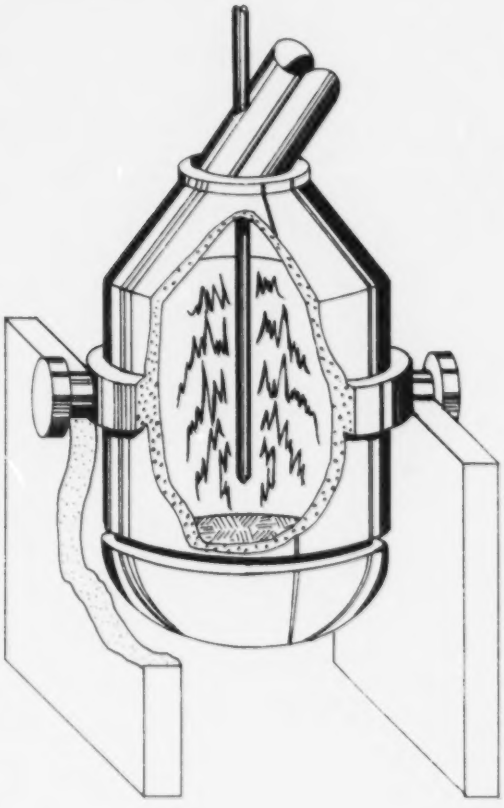
44

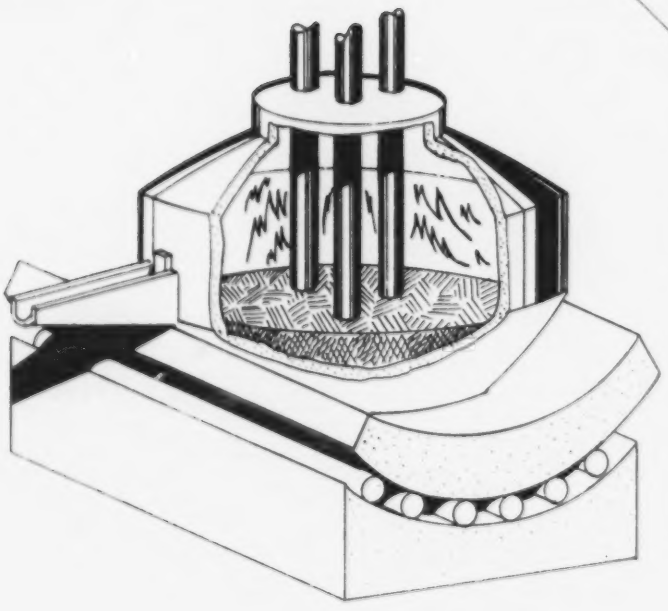
The Making of Steel



Steelmaking Furnaces

Basic Oxygen Furnace





Electric Arc Furnace

LESSON
Sort & Produce

HAVE YOU EVER WONDERED? ***What is the process for turning iron into the steel we use every day?***

Steel, in one way or another, fits into nearly every facet of our daily lives. Steel is found in so many products, from cars to buildings to toasters, that we often take it for granted, but the process of making steel involves the efforts of many people and technologies.

Steel is an alloy of iron with a small amount of carbon (less than two percent) with other elements sometimes added to give the steel specific properties. The iron used to make steel can come from either iron ore, scrap steel, or both. Many of the steel mills in the United States are integrated mills. An **integrated mill** has both a blast furnace for producing molten iron from ore and a steelmaking furnace, usually a **basic oxygen furnace**, which refines steel from iron ore and up to 30 percent scrap steel.

Some integrated mills also have an **electric arc furnace**, which refines steel from scrap steel (up to 100 percent) and/or direct reduced iron. **Mini-mills**, which do not have a blast furnace on site, also make use of electric arc furnaces.

Mining — Sorting the Ore from the Earth

Iron usually exists in nature as iron oxides in ores which also contain silica sand (SiO_2) and other impurities such as sulfur (S), phosphorous (P), aluminum (Al), and manganese (Mn). In the United States, the most common ores in order of importance are hematite (Fe_2O_3, a red-colored mineral), magnetite (Fe_3O_4, a black, highly magnetic mineral), and limonite ($Fe_2O_3 \cdot H_2O$, a yellow brown compound). Deposits of iron ore may occur near the surface and are mined by removing the layers of soil covering the ore with huge power shovels, or they may be deeply buried and are therefore mined by digging and drilling deep into the earth. Sometimes blasting is required to break apart the ore-bearing rock.

Beneficiation — Sorting the Oxide from the Ore

Iron ores typically contain 20 to 35 percent iron. High grade ores (those containing a high concentration of iron) can go directly from the mine to the blast furnace. However, lower grade ores are being used more often as the deposits of high grade ores are depleted. Before the iron oxide can be used, it must be beneficiated (concentrated) by removing some of the sand and rock. Sometimes washing, crushing and screening the ore is enough, but often more complex methods must be used.

One such method utilizes the principle of **ferromagnetism**. In any element, the spin of an electron creates a tiny magnetic effect. When electrons are paired, their spins are in opposite directions and their magnetic effects cancel out. Many of the transition elements have unpaired electrons in the *d* subshell, and net magnetic effects exist, but they are so small that they are insignificant. However, the atoms of three transition metals — iron, nickel and cobalt — have just the right size and shape so that their magnetic effects are strong enough to be significant.

In the magnetic method of beneficiation, iron ore is crushed, ground into a powder and passed through magnetic separators which collect the iron-bearing particles.

An alternative to magnetic separation is **flotation**. In this process, the ore is crushed and loaded into a flotation cell which contains a dense solution. The heavier iron-bearing particles sink to the bottom of the cell where they can be collected.

Reduction — Sorting the Iron from the Oxide

Before iron can be utilized for making steel, it must be reduced (separated from its oxygen) and purified. This can be done either in a blast furnace or by direct reduction.

A blast furnace tower may be taller than a 20 story building and more than 13 meters at the base. Temperatures in the tower range from 500 degrees Celsius at the top to 1600 degrees at the bottom, hot enough to melt iron. The reducing agent used in the blast furnace is carbon in the form of coke, produced by heating coal in the absence of air. Iron ore, coke, and limestone are charged (loaded) into the top of the tower. As they settle down through the temperature gradient, the carbon burns and a series of reduction reactions occurs between carbon and iron, removing oxygen and forming pure iron and carbon dioxide. At the same time, the impurities react with the limestone to form a molten mixture called slag. By the time the iron reaches the bottom of the tower, it is about 95 percent pure and can be tapped off in its liquid state. The slag, which is less dense than the molten iron, floats on it and is tapped off separately. Slag can be used to make cement and insulation materials.

In the direct reduction process, iron oxide is reduced at lower temperatures, so no melting is involved. The reducing agents can be gas mixtures derived from natural gas or gases formed from heating coal.

Recycling — Sorting the Scrap from the Fluff

Using scrap steel for manufacturing new steel helps conserve natural resources and energy, and diverts scrap steel from the landfill (saving space). Scrap metals, including copper, zinc and other metals in addition to steel, are often found commingled with other materials such as plastics and glass. For scrap metals to be used in producing new products, they must be sorted from other components of the mix.

A major source of scrap steel is "junked" automobiles. The first step in recycling an automobile is to remove components such as window glass, batteries, and tires. When the automobile has been stripped, it is shredded. Valuable scrap metals are extracted from the shredded material for recycling. The leftover portion that cannot be recycled is landfilled or incinerated.

The steel used in automobiles generally is alloyed with other materials. If the proportions of the alloying materials are high enough to affect the properties of the new steel, they must be separated out in the liquid state. Techniques include controlling temperature, pressure, chemistry, and momentum by stirring.

Steelmaking — Producing the Alloy from the Iron

Once the iron from ore has been reduced, or the iron from scrap has been separated, it is transferred to a furnace for refining into steel.

At the integrated mill, scrap steel and liquid iron are charged into the barrel-shaped basic oxygen furnace and pure oxygen is injected into the liquid bath. The oxygen reacts with iron to form iron oxide; carbon then reacts with iron oxide to form carbon monoxide, releasing the iron. In this way, the carbon content can be quickly lowered to the appropriate proportion for steel (0.05–1.6 percent). Other elements may be added to give the alloy specific properties.

At the mini-mill, solid scrap steel, and sometimes direct reduced iron, are charged into an electric arc furnace. An electric current is sent through large graphite electrodes through the raw materials, creating extreme heat which melts the iron. The molten iron then goes to a metallurgy facility where a variety of treatments are performed to manufacture steel to exact specifications.

Once the molten steel is produced by either the basic-oxygen or electric arc techniques, it is cast in stationary molds or continuously cast into long slabs, and moved through a series of shaping, heating, and cooling processes to produce various sizes, shapes, and types of solid steel.

ACTIVITY 5

Sorting Commingled Metals

Learning Outcomes

Students will be able to:

- describe the properties of aluminum, iron, and lead
- identify metals in a mixture
- calculate the representative composition of metals extracted from a mixture

Time

One class period

Safety Tips

Lead shot leaves a residue in water or when handled. Students must wear goggles, gloves, and aprons.

Materials/Equipment

Aluminum foil
Bar magnets
Beakers (500 mL)
Beakers (1000 mL)
Coffee filters
Lab tray
Lead shot
Paper towels
Petri dishes
Rubber bands
Scrap metals (aluminum pop tabs, steel O-rings, bits of 10-gauge copper wire)
Spoon (plastic)
Steel shot

Figures/Tables

Electron Configurations of Some Transition Metals, page 39

Ratio of Space to Diameter in Some Transition Metals, page 40

Procedure

1. Prepare aluminum foil "shot." Aluminum shot available from laboratory supply houses generally is too large to use for this activity. Recruit students to assist in preparation of the aluminum "shot." Tear off small pieces of aluminum foil and roll the pieces into spheres the size of the steel and lead shot. Roll the spheres tightly so there are no internal air spaces. Prepare one gram of aluminum "shot" for each lab group.
2. Use the *Background: Student*, pages 35 and 36, to discuss the need for sorting metals from ore for beneficiation and for sorting metals from a commingled mix for recycling.
3. Copy onto transparencies or use as handouts the figures *Electron Configurations of Some Transition Metals* and *Ratio of Space to Diameter in Some Transition Metals*. Use the figures and a Chemistry text to review the basic principles of ferromagnetism, electron configuration, and density. Remind students that electron configuration and atomic mass affect the properties of the elements.
4. Divide the class into lab groups. Provide each group with a bar magnet, a 500-mL beaker, a 1000-mL beaker, a coffee filter, a rubber band, three petri dishes, several paper towels, a plastic spoon, lab tray, and the following mixture:

80 grams steel shot	(about 20 mL if measuring in a beaker)
60 grams lead shot	(about 10 mL)
1 gram aluminum "shot"	(about 10 mL)

Do not reveal to the students the proportions of metals in the mixture.

5. Copy and distribute to each student *Activity 5: Student*, pages 41 and 42. Review the procedures and safety tips. Instruct lab groups to proceed with sorting the metals in the mixture.
6. Follow up the activity with the following teacher demonstration:

   Sort a mixture of scrap metals made of aluminum pop tabs, steel O-rings and bits of 10-gauge copper wiring. For the flotation solution, use a clear carbonated soft drink such as ginger ale. Use of the soft drink simulates froth flotation, a variation on the flotation technique of sorting in which a combination of low density and surface tension causes the aluminum to rise.

Collecting and Analyzing Data

1. Ask students to identify the metals in the light fraction (aluminum), magnetic fraction (iron), and heavy fraction (lead) based on student predictions. Compare results from the various lab groups.
2. Assist students in calculating for each fraction its percentage of the total mixture using the following formula:

$$\frac{\text{Mass of the fraction}}{\text{Mass of the total mixture}} \times 100$$

Compare percentages among lab groups.

Drawing Conclusions

Q1: Show the transparency Electron Configuration of Some Transition Metals. *Ask the students to explain why many of the transition elements have unpaired electrons in the* 3d *orbital but only iron, nickel and cobalt are ferromagnetic.*

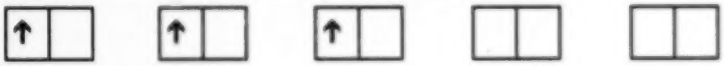
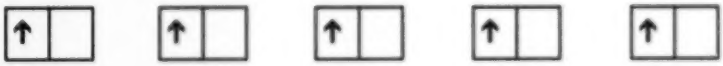
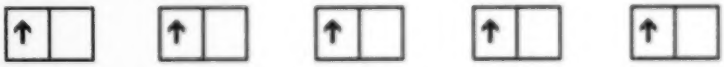
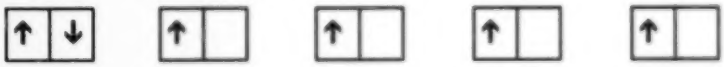
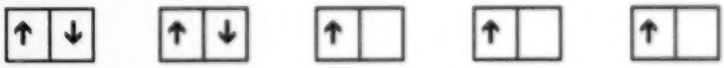
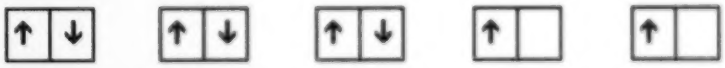
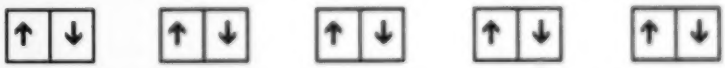
A1: Show the transparency *Ratio of Space to Diameter in Some Transition Metals*. Ferromagnetism depends not only on the presence of unpaired electrons, but also on the spacing between atoms and the diameter of the *3d* orbit.

To produce a magnetic effect, the spins of the *3d* electrons of adjacent atoms must align in a parallel direction by a phenomenon called spontaneous magnetization. For this alignment to occur, the ratio of the space between atoms to the diameter of the *3d* orbit must be between 1.4 – 2.7. The ratios of iron, nickel and cobalt fall within this range, but for most transition elements, they do not.

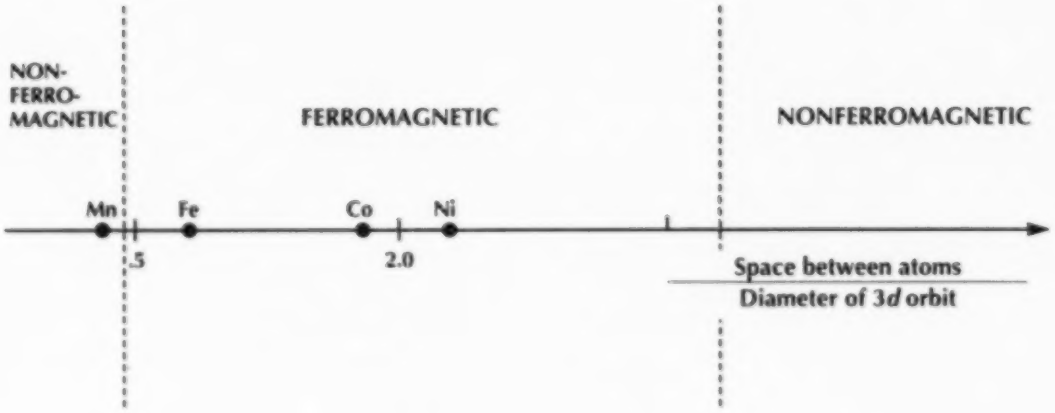
Q2: Why was a carbonated beverage used instead of plain water for sorting out the light fraction in the follow-up teacher demonstration?

A2: Because of their size, the aluminum pop tabs would sink in plain water. The carbonated soft drink produces bubbles which buoy the pop tabs up to the surface where they can be collected.

Electron Configurations of Some Transition Metals

ATOM	ELECTRON CONFIGURATION 3*d* ORBITALS	UNPAIRED 3*d* ELECTRONS
V		3
Cr		5
Mn		5
Fe		4
Co		3
Ni		2
Cu		0

Ratio of Space to Diameter in Some Transition Metals



ACTIVITY 5
Sorting Commingled Metals

Procedure

1. In this activity, you will work with your lab group to sort metals magnetically and by flotation in water. You will need:
   - Mixture of metals (aluminum, lead, and iron)
   - 1 bar magnet
   - 1 beaker (500-mL)
   - 1 beaker (1000-mL)
   - 1 coffee filter
   - 1 lab tray
   - 3 petri dishes
   - 1 rubber band
   - 1 spoon (plastic)
   - Paper towels

Safety Tips

Lead shot leaves a residue in water or when handled. Exercise caution when handling lead. Wear goggles, gloves, and an apron.

2. **Examine the mixture of metals.**

   Record your observations on the chart "A Mixture of Metals," page 42. Mass the mixture and record the mass. Remember to subtract the mass of the container from the total mass to obtain the mass of the mixture.

3. **Magnetic, Light, or Heavy?**
   a) Refer to "Magnetic or Non-Magnetic?", page 42. Examine the electron configurations and predict which of the three metals will be magnetic.
   b) Refer to a periodic table of the elements to find the atomic mass of aluminum, iron, and lead. Predict for each whether it will sink or float in the flotation solution (water). Record your predictions in the chart "Heavy or Light?"

4. **Magnetic Fraction.**
   a) Label a petri dish "Magnetic Fraction."
   b) Work in the lab tray to avoid losing any of the metals. Dip the bar magnet into the mixture of metals, stir briefly, and pull the magnet out. Wipe the metal that adheres to the magnet into the petri dish.
   c) Repeat step b) until no more metal adheres to the magnet.
   d) Mass the metal in the petri dish. Record the mass and any other observations in the chart "A Mixture of Metals."

5. **Light Fraction.**
   a) Label a petri dish "Light Fraction."
   b) Pour 250-mL of water (the flotation solution) into the 500-mL beaker. Pour the mixture of metals into the flotation solution.
   c) Use the plastic spoon to retrieve the metal that floats. Place the metal in the petri dish. Pat the metal dry with paper towels.
   d) Mass the metal in the petri dish. Record the mass and any other observations in the chart "A Mixture of Metals."

6. **Heavy Fraction.**
   a) Label a petri dish "Heavy Fraction."
   b) Make a funnel filter from a coffee filter and, with a rubber band, secure it in place in the 1000-mL beaker.
   c) Pour the flotation solution with the remaining metal through the filter. If metal adheres to the beaker, you may need to add more water and pour it through the funnel again. Transfer the metal in the funnel to the petri dish. Pat the metal dry with paper towels.
   d) Mass the metal in the petri dish. Record the mass and any other observations in the chart "A Mixture of Metals."

Collecting and Analyzing Data

1. Based on your predictions and observations, identify the metals in the magnetic fraction, light fraction, and heavy fraction. Compare your results with other lab groups.
2. Calculate for each fraction its percentage of the total mixture using the following formula:

$$\frac{\text{Mass of the fraction}}{\text{Mass of the total mixture}} \times 100$$

Compare your percentages with other lab groups.

A Mixture of Metals

	VISUAL OBSERVATIONS	METAL	MASS (g)	% OF TOTAL MIXTURE
Total mixture		Al, Fe, Pb		100
Magnetic fraction				
Light fraction				
Heavy fraction				

Magnetic or Non-Magnetic?

For an element to be magnetic, it must have unpaired 3d electrons. Examine the electron configurations of the elements below. Predict whether the metal will be magnetic or non-magnetic.

ALUMINUM (Al) $3s^2 3p^1$	IRON (Fe) $4s^2 3d^6$	LEAD (Pb) $6s^2 4f^{14} 5d^{10} 6p^2$

Heavy or Light?

Refer to the periodic table for atomic mass of aluminum, lead and iron. Predict for each metal whether it will sink (heavy) or float (light) in a flotation solution.

ALUMINUM (Al)	IRON (Fe)	LEAD (Pb)

Drawing Conclusions

1. Many of the transition elements have unpaired electrons in the *3d* orbital but only iron, nickel and cobalt are magnetic. Why?

2. Why was a carbonated beverage used instead of plain water for sorting out the light fraction in the follow-up teacher demonstration?

ACTIVITY 6

Melting Alloys

Learning Outcomes

Students will be able to:

- observe the change in a metal from the solid to the liquid state
- identify differences in melting points of various alloys
- explain how the addition of alloying elements to a base metal may affect the melting point

Time

One class period

Safety Tips

Onion's fusible alloy contains lead and should be handled with forceps or tongs. Do not allow students to melt this alloy with the soldering iron.

Review soldering iron safety procedures. Do not use solders containing lead or cadmium. Perform soldering on a heat-resistant surface in a well-ventilated room. Students must wear goggles, work gloves, and apron.

Materials/Equipment

Aluminum (foil)
Aluminum (pie pans)
Beakers (500-mL, Pyrex or Kimax)
CRC Handbook of Chemistry and Physics or other text which provides melting points and descriptions of metallic elements
Hot plates
Onion's fusible alloy
Scissors
Soldering irons
Steel shot
Test tubes (20x150 or similar size, Pyrex or Kimax)
Test tube clamps
Tongs or forceps
Wire solders (tin-antimony or tin-silver)

Procedure

1. Copy onto transparencies *The Making of Steel*, page 33, and *Steelmaking Furnaces*, page 34. As you show the transparencies, refer to the *Background: Student*, pages 35 and 36, to discuss the processes of making steel. Focus on the process of melting the metals and other elements to form alloys. For more information on alloys, see *Background: Student* on pages 5 and 6. Review the concept of crystal structure of metals.
2. Copy and distribute to each student *Activity 6: Student*, pages 45 and 46. Divide the class into lab groups. Provide each group with a two-centimeter square of aluminum foil, an aluminum pie pan, a 500-mL beaker, forceps or tongs, a hot plate, a chunk of Onion's alloy about the size of a pea, scissors, a soldering iron, a 10 centimeter piece of wire solder, 15–20 pieces of steel shot, four test tubes, and a test tube clamp.
3. Review the procedures outlined in *Activity 6: Student*. Note that this activity requires research by the students to determine the melting points and characteristics of various metals. For large classes or if the number of reference books is limited, it might be convenient to either assign elements to different groups or make copies of the pertinent pages for groups to use at their stations.
4. Emphasize safety tips and demonstrate proper use of the soldering iron. Tell the students which type of solder they will be using (for instance, 95 percent tin–5 percent antimony, or 98 percent tin–2 percent silver). Instruct students to proceed with the activity.
5. After students have finished the hot water test, collect the test tubes containing the Onion's alloy. To remove the metal from the test tube, quickly dip the test tube in and out of a hot water bath. The metal will easily slip out of the test tube and can be reused by the next class.

Collecting and Analyzing Data

1. Ask students to compare their observations with their predictions. Compile data from lab groups into a class chart.
2. For each element listed in the chart "Melting Points of Common Elements," instruct groups to list a few interesting facts and uses which relate to their observations. Lead a class discussion on these facts and uses.

Drawing Conclusions

Q1: Did the melting points of any of the alloys used in this activity differ significantly from the melting points of the individual elements? Explain.

A1: Addition of alloying elements to a base metal affects the crystal structure of the base metal. In the case of Onion's alloy, this alteration in crystal structure leads to a melting point of approximately 92 degrees Celsius, significantly lower than the melting points of bismuth, lead, or tin.

Q2: Solder is used to join metal surfaces to make reliable electrical connections, make a joint liquid- or gas-tight, or seal the spaces in a joint. How does the melting point of solder make it useful for joining other metals?

A2: Solder has an intermediate melting point. The metals it is used to join (steel, stainless steel, copper) have high melting points. Melted solder flows or is drawn by surface tension into tiny crevices in the metal surface. The surface may melt slightly at the point of contact with the solder, but overall the metal surface remains intact.

If the melting point of the solder were as low as Onion's alloy, it could not be used to seal hot water pipes or to make electrical connections.

ACTIVITY 6
Melting Alloys

Procedure

1. In this activity, you will work with your lab group to melt various metal alloys. This activity should be performed on a heat-resistant surface in a well-ventilated room. You will need:
   - aluminum foil (2-centimeters square)
   - 1 aluminum pie pan
   - 1 beaker (500-mL, Pyrex or Kimax)
   - 1 hot plate
   - 1 chunk of Onion's fusible alloy (pea-size)
   - 1 pair of scissors
   - 1 soldering iron
   - 15-20 pieces of steel shot
   - 4 test tubes
   - 1 test tube clamp
   - 1 pair of tongs or forceps
   - 10 centimeters of wire solder

Safety Tips

Onion's fusible alloy contains lead. Handle this alloy with tongs or forceps. Do not attempt to melt Onion's alloy with the soldering iron. Exercise caution when operating the soldering iron. Do not use solders other than the tin-antimony or tin-silver solders provided by your teacher. Do not touch hot metals with bare hands. Wear goggles, work gloves, and an apron.

2. **Predict melting points of alloys.**
   a) Refer to a table or text which lists the melting points of metals. Record the melting points in the chart "Melting Points of Common Elements," page 46.
   b) Examine the aluminum foil, Onion's alloy, solder and steel shot. Refer to the composition of each of these items in the chart "Melting Metals," page 46. Predict whether each alloy will melt in hot (near-boiling) water or with a soldering iron.

3. **Hot water test.**
   a) Place the following in four separate test tubes. Label the test tubes.
      - Onion's alloy.
      - Steel shot.
      - Small pieces of aluminum foil; cut the square into pieces which will fit into a test tube.
      - Small pieces of solder; snip off a four-centimeter strip of solder, then cut the strip into small pieces to fit in the test tube.
   b) Set the test tubes upright in a beaker. Fill the beaker with water to three-quarters full.
   c) Set the beaker on the hot plate and heat the water. Observe whether or not any of the alloys melt when the water approaches boiling. Record your observation in the chart "Melting Metals."
   d) Use a test tube clamp to remove the test tubes from the water bath.
      - Set aside the test tube containing the Onion's alloy for your teacher to collect.
      - Empty the contents of the other test tubes into the aluminum pie pan.

5. **Soldering iron test.**

   Work in the aluminum pie plate for this test. Record observations for each step in the chart "Melting Metals."
   a) Plug in the soldering iron and allow it to heat.
   b) Touch the tip of the hot soldering iron to the aluminum for five seconds. Remove the soldering iron and observe whether or not the aluminum melted.
   c) Touch the tip of the hot soldering iron to the steel for five seconds. Remove the soldering iron and observe whether or not the steel melted.
   d) Hold the tip of the soldering iron next to the tip of the wire solder for five seconds. Remove the soldering iron and observe whether or not the solder melted.

Collecting and Analyzing Data

1. Compare your observations with your predictions and with other lab groups.

2. Use the *CRC Handbook of Chemistry and Physics* or other reference book to look up each element listed in the chart "Melting Points of Some Elements." For each element, make a list of interesting facts and uses that relate to this activity.

Melting Points of Common Elements

ELEMENT	MELTING POINT, °C	ELEMENT	MELTING POINT, °C
Aluminum (Al)		Lead (Pb)	
Antimony (Sb)		Manganese (Mn)	
Bismuth (Bi)		Silicon (Si)	
Carbon (C)		Silver (Ag)	
Iron (Fe)		Tin (Sn)	

Melting Metals

ALLOY	MELTS IN HOT WATER? (APPROX. 92 °C)		MELTS WITH SOLDERING IRON? (BELOW 427 °C)	
	Predicted	Observed	Predicted	Observed
ALUMINUM PIE PAN (Al with small amounts of Si, Mn, Fe)				
ONION'S ALLOY (Bi with small amounts of Pb, Sn)				
SOLDER (Sn with small amounts of either Sb or Ag)				
STEEL SHOT (Fe with small amount of C)				

Drawing Conclusions

1. Did the melting points of any of the alloys used in this activity differ significantly from the melting points of the individual elements? Explain.

2. Solder is used to join metal surfaces to make reliable electrical connections, to make a joint liquid- or gas-tight, or to seal the spaces in a joint. How does the melting point of solder make it useful for joining other metals?

58

Glossary

alloy a mixture of two or more elements or compounds, at least one of which is a metal.

alloying element the component of an alloy added in small proportions to give specific chemical and physical properties. Carbon is the most important alloying element of steel. Many other alloying elements of steel are transition metals.

base metal the primary component of an alloy. Iron is the base metal of steel.

basic oxygen furnace a steelmaking furnace in which oxygen is injected into the molten metal starting a chain of reactions which purifies the iron. Uses up to 30 percent scrap steel.

beneficiation improving the quality of iron ore by removing excess sand and rock.

disassembly take apart for reuse or recycling.

ductility a measure of the ability to undergo a change in shape without rupturing.

electric arc furnace a steelmaking furnace that uses virtually 100 percent scrap steel to make new steel. An electric current is sent by large electrodes through the scrap metal, creating high heat that melts the steel.

ferrous iron based metals, including steel; iron is the element which gives steel its magnetic quality. The term is derived from the Latin *ferrum*, meaning iron.

ferromagnetic a material which has significant magnetic properties similar to iron. Three transition elements, iron, cobalt, and nickel, are ferromagnetic.

flotation a method of sorting in which dense materials sink and light materials float in a solution.

fluff shredded scrap residue from used automobiles. Fluff contains nonmetals such as plastics, glass, rubber, carpet, and dirt.

galvanize to coat steel or iron with zinc to provide corrosion resistance.

integrated mill a steel mill that has both a blast furnace and steelmaking furnace on site.

malleability the ability to be shaped. Also called "formability."

metallic bond a type of bond in which electrons are shared among metal atoms in a solid.

mini-mill a steel mill which has an electric arc furnace on site, but no blast furnace.

nonferrous metal containing no iron.

scrap products that have completed their useful life, such as appliances, cars, construction materials, ships, and steel cans; also materials that are a byproduct of processing and manufacture. Steel scrap is highly recyclable into new steel products.

solder a metal used to join other metal surfaces to make reliable electrical connections, make a joint liquid- or gas-tight, or seal the spaces in a joint. For a solder to be effective it must have a lower melting point than the metal(s) that it joins.

steel an alloy comprised of iron, carbon, and other metals. Steel is used widely used to make a variety of products. Steel scrap is recycled to make new steel products.

transition metals elements located generally in the center of the periodic table. Iron, copper, gold, and nickel are examples of transition metals. Transition metals have the properties usually associated with metals (e.g., strength, ductility, malleability, metallic luster, and conductivity of heat and electricity). Transition metals are important in making steel; iron is the base metal and many other transition metals are used as alloying elements.

Bibliography

Lesson: Supply & Demand

Brady, James E. and Gerard E. Humiston. *General Chemistry Principles and Structure*. 2d ed. Wiley & Sons: New York, NY, 1975.

Ebbing, Darrell D. *General Chemistry*. 3rd ed. Houghton Mifflin: Boston, MA, 1990.

Garrett, Alfred B., W.T. Lippincott, and Frank H. Verhoek. *Chemistry: A Study of Matter*. 2nd ed. Xerox: Lexington, MA, 1972.

Herron, Dudley, David Kukla, Cliff Schrader, Julia Erickson and Michael DiSpezio. *Chemistry*. Heath: Lexington, MA, 1987.

Smith, William F. *Principles of Materials Science and Engineering*. 2nd ed. McGraw-Hill: New York, NY, 1990.

Lesson: Collect & Haul

Herron, Dudley, David Kukla, Cliff Schrader, Julia Erickson and Michael DiSpezio. *Chemistry*. Heath: Lexington, MA, 1987.

Jackson, F.R. *Recycling and Reclaiming of Municipal Solid Wastes*. Noyes Data Corp: Park Ridge, NJ, 1975.

Kiser, Kent. "Total Car Recycling: Just a Green Dream?" *Scrap Processing and Recycling*. Vol.49: No.5, pp 42-48. Institute of Scrap Recycling Industries, Sept. 10, 1992.

Labana, S.S., "Recycling of Automobiles," Ford Motor Company, Dearborn, MI, 1990.

Serafin, Raymond. "Carmakers Say Recycling Can Mold Positive Image." Automotive News. Nov. 15, 1993, p 30.

Smith, William F. *Principles of Materials Science and Engineering*. 2nd ed. McGraw-Hill: New York, NY, 1990.

Lesson: Sort & Produce

American Iron and Steel Institute. *Steel Processing Flow Lines*. Washington, DC.

American Iron and Steel Institute. *The Science of Steelmaking*. Audio/Visual Teaching Aid. Washington, DC.

Brady, James E. and Gerard E. Humiston. *General Chemistry Principles and Structure*. 2d ed. Wiley & Sons: New York, NY, 1975.

Ebbing, Darrell D. *General Chemistry*. 3rd ed. Houghton Mifflin: Boston, MA, 1990.

Herron, Dudley, David Kukla, Cliff Schrader, Julia Erickson and Michael DiSpezio. *Chemistry*. Heath: Lexington, MA, 1987.

Jackson, F.R. *Recycling and Reclaiming of Municipal Solid Wastes*. Noyes Data Corp: Park Ridge, NJ, 1975.

Smith, William F. *Principles of Materials Science and Engineering*. 2nd ed. McGraw-Hill: New York, NY, 1990.

List of Figures/Tables

	Page
Crystal Structure of Iron	3
Crystal Structure of Steel	4
Average Composition of a U.S. Built Car	17
Example of Electromagnetic Equipment Used in Automobile Shredding Scrap Yards	18
Scheme for an Automobile	23
Composition of Select Car Parts	24
The Making of Steel	33
Steelmaking Furnaces	34
Electron Configurations of Some Transition Metals	39
Ratio of Space to Diameter in Some Transition Metals	40

Did You Know? Steel Recycling

- For each ton of steel recycled, 2500 pounds of iron ore, 1000 pounds of coal and 40 pounds of limestone are saved.
- Through all of its recycling efforts, the steel industry saves an average of 600 trillion Btu's each year, the energy equivalent to electrically power more than 18 million households for a year.
- Steel cans account for more than 90 percent of the food can market, three percent of the beverage can market and the majority of the paint and aerosol can markets.
- Steel products, such as cars, containers and appliances, contain about 25 percent recycled steel; heavy products, such as structural beams and plates used in construction, contain virtually 100 percent recycled steel.
- Already, more than 66 percent of all steel in the U.S. is recycled into new products. Cars, appliances, machinery, and even demolished buildings provide a constant supply of steel scrap that is used to produce new steel.
- Steel is used in construction to build factories, stores, office buildings, and transportation systems. This dependable, durable, affordable material is the heart of the American way of life.
- Consumers have relied on the steel can for the preservation of fruits and vegetables, longer shelf life and tamper resistance. Often called "tin" cans, steel cans come in approximately 600 sizes, shapes and styles, containing over 2,500 different products.
- For decades, bridge builders have selected steel to expand the world's ground transportation systems. Over the years, new higher strength steels have been developed, including those with chemical properties that inhibit corrosion and deterioration.
- Steel, because of its structural uses, is often unseen. Steel nails, screws and bolts hold together our homes, schools and offices, and have for generation after generation.
- Steel is now used for framing houses as well as providing the structure for commercial buildings.
- Today's automobiles offer many steel applications: corrosion-resistant coated sheet steels in body panel configurations, and steel bars used in axles, gears, bearings, drive trains, engine parts, and steering and suspension assemblies. Steel wire also forms integral parts of the whole car as it serves to operate and control the vehicle. Steel tubing helps to reduce weight and cuts production costs.
- During the 19th century, iron and steel made possible the development of the American transcontinental railroad system. Steel formed our nation's arteries — it carried railroads across the nation and roads across the rivers. The "iron horse" of yesterday was known for its relative speed and reliability. Today's modern rail transportation maintains that reputation in a faster-paced world. And steel continues to be the material of choice for building the systems that link people and products across the country.
- One hundred years ago, steel in construction made possible the first skyscrapers to be built. Continuing advances in architectural design and steel technology make it possible to use less steel to build larger, taller, stronger and more flexible structures.

Resources

Contact the following organizations for information on recycling and other materials.

Aluminum Recycling Association
1000 16th Street, NW, Suite 400
Washington, DC 20036
202/785-0550

American Forest and Paper Association
1250 Connecticut Avenue, NW, Suite 200
Washington, DC 20036
202/463-2420

American Iron and Steel Institute
1101 17th Street, NW
Suite 1300
Washington, DC 20036
202/452-7100

American Plastics Council
1275 K Street, NW, Suite 500
Washington, DC 20005
202/371-5319

Appliance Recycling Centers of America, Inc.
2601 Broadway Road, NE
Minneapolis, MN 55413
612/331-1000

Aseptic Packaging Council
1000 Potomac Street, NW, Suite 401
Washington, DC 20007
202/333-5900

Automotive Recyclers Association
3975 Fair Ridge Drive
Suite 20, Terrace Level N
Fairfax, VA 22033-2906
703/385-1001

Can Manufacturers Institute
1625 Massachusetts Ave. NW
Washington, DC 20036
202/232-4677

Glass Packaging Institute
1627 K Street, NW, Suite 800
Washington, DC 20006
202/887-4850

Institute of Scrap Recycling Industries
1325 G Street NW
Washington, DC 20005
202/466-4050

Keep America Beautiful, Inc.
Mill River Plaza
9 West Broad Street
Stamford, CT 06902
203/323-8987

National Recycling Coalition, Inc.
1101 30th Street, NW, Suite 305
Washington, DC 20007
202/625-6406

National Wildlife Federation
1412 16th Street, NW
Washington, DC 20036
202/797-6800

Steel Recycling Institute
680 Andersen Drive
Pittsburgh, PA 15220-2700
412/922-2772

U.S. Bureau of Mines
810 7th Street NW
Washington, DC 20241
202/501-9649

U.S. Geological Survey
12201 Sunrise Valley Dr.
Reston, VA 22092
703/648-4000

Teacher Evaluation

Please return evaluation form to:

***Cycles for Science**/Chemistry*
Steel Recycling Institute
680 Andersen Drive
Pittsburgh, PA 15220-2700
412/922-2772

Name _____ School _____

Address _____ Phone _____

City _____ State _____ Zip _____

Secondary grade subject area(s) _____

Grade level(s) taught _____ Number of students _____

We value your comments on the ***Cycles for Science*** curriculum. Please enclose a copy of any or all of the lessons with your comments and changes marked in red. If you have added curriculum or teaching aids, please enclose photocopies with an explanation.

Make further comments here:

If we use your comments or ideas to improve the curriculum, you will be credited in the acknowledgements of the 2nd edition of ***Cycles for Science**/Chemistry*.